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E X P E R I M E N T S

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B L E A C H I N G.

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Των γὰρ ὄντων ἀγαθῶν καὶ καλῶν ὕδιν, ἀνευ πόνης καὶ ἐπιμελείας
θεοὶ διδάσκουσιν ἀνθρώπους. Prod. de Hercul.

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ADVERTISEMENT.

AT the desire of the Honourable Board of Trustees for the improvement of fisheries and manufactures in *North Britain*, the following treatise was composed, read in different lectures, and the experiments, so far as it was possible, were performed before the bleachers of this country. It is now published in consequence of a petition presented by the bleachers to the Honourable Board of Trustees.



A general plan of the work.

P A R T I.

S E C T. I.

Connection of chymistry with the arts.

S E C T. II.

Different practical methods of bleaching.

P A R T II.

S E C T. I.

Steeping.

S E C T. II.

Bucking and boiling, or the application of alkaline lyes.

S E C T. III.

Alternate watering and drying.

S E C T.

[v]

S E C T. IV.

Souring, or the application of acids.

S E C T. V.

Hand-rubbing with soap and water ; rubbing-boards.

P A R T III.

S E C T. I.

Blue pearl ashes.

S E C T. II.

White pearl ashes.

S E C T. III.

Muscovy or blanch ashes.

S E C T. IV.

Cashub ashes.

S E C T.

S E C T. V.

Marcoft ashes.

S E C T. VI.

Method of manufacturing these ashes at home.

P A R T IV.

S E C T. I.

The natural effects of these ashes, and of other bodies, on unbleached cloth.

S E C T. II.

Of the cause and effects of hard water, and the methods of softening it.

S E C T. III.

The effects of steel and coal waters on cloth, and the cure.

S E C T. IV.

Some considerations with regard to the further improvement of the linen manufacture.

EXPERIMENTS
ON
BLEACHING.

PART I.

SECT. I.

Connection of chymistry with the arts.

MANUFACTURES are to a country, what aliment is to the human body. They supply all wastes; hinder a nation from preying on itself; give it vigour for necessary duties; diffuse the look of health and happiness over its face; and lay up a store of strength for extraordinary exertions of its power. A wise government will no more neglect, or overlook the manufactures of a country, than a wise physician the diet of one committed to his care.

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LET us take a cursory view of the different methods necessary to be employed in establishing manufactures; for without all, or most of those, it is in vain to expect that these will ever arrive at any degree of perfection.

WE may reduce all the different ways made use of to promote manufactures, to two general sources; the wise regulations of the government, and the united efforts of the people where these manufactures are established.

THE influence of the government consists in encouraging home manufactures, by granting protection, privileges, immunities, and bounties, to such as carry them on; by taking off all duties on the materials used in them; by establishing proper trustees to have the inspection of them, and companies with suitable privileges; by settling proper funds to be distributed in rewards to those who excel; by not making it too burthensome and expensive for the manufacturers to obtain

Sect. I. ON BLEACHING. 3

obtain good laws ; and by a proper regulation of the fashions at their source.

BUT all these advantages are of small avail, if a ready market is not opened : for it is an axiom in trade, That manufactures increase only in proportion to the demand for them. Here then will the wise politician be again discovered, in discouraging all foreign manufactures of the same kind, by prohibitions, or high duties equivalent to them.

THANKS to the present government for their great regard and attention to the manufactures of *North Britain*. More has been done for it in this way, within these few years, than in all those ages which went before. In after times it will be the distinguishing character of the present, That manufactures and industry were encouraged in *North Britain*, nay, introduced into its remotest parts. What advantage this will be to *South Britain*, is evident to one who considers, that the greatest part of our gains must at last centre there ; and that as much

linen was manufactured, even in the confusion of the year 1745, as in any of the preceding. This fact merits the utmost attention ; and shows, that there is not a more proper and effectual antidote against rebellion, than industry and manufactures.

IT is not enough that a government makes wise regulations. The leading people of a country must lend their united assistance. From them alone a true spirit takes its rise, and diffuses itself by degrees over the generality of a country. The lower ranks of people are capable of following, though not made for leading. To discover the good effects of a general spirit in people of rank, let us cast our eyes on a neighbouring island. What well-judged regulations with regard to the whole progress of the linen manufacture ! what attention and encouragement to every useful project ! what union and spirit in carrying it into execution ! what a judicious distribution of public and private bounties ! what a wise institution is their linen-hall in *Dublin*, in affording a constant market for foreign merchants, and

Sect. I. ON BLEACHING. 5

a constant check to the frauds of private dealers ! To their eternal honour be it said, no nation ever made a better use of so bad a commonalty.

THEY turn even the vices of their nation to the public benefit. Their foundling-hospital, erected for the reception of those children, whom parents either cannot maintain, or do not chuse to own, is become a seminary of industry. Of 1500 children, those who are capable from their age, are employed chiefly in spinning flax and wool. I had the pleasure lately to see 150 girls, between six and twelve years old, spinning with both hands. A *Scots* woman employed to teach them, has a salary of *L.* 30 a-year settled on her by the trustees. It is no difficult matter to foresee what great advantage this hospital will be to that nation in a few years. These children, when grown up, will spread themselves over the country, teach others, double the quantity of yarn, reduce its price, and put it in their power to undersel others. Such a wise regulation in this country, would be the means of saving the

6 EXPERIMENTS Part I.

the lives of many innocent children, and many unhappy mothers, and turn to some national advantage what we cannot perhaps altogether restrain.

I should be guilty of an injustice to this country, were I not in a public manner to own the many obligations which we lie under to the Honourable board for the improvement of fisheries and manufactures in *Scotland*. These gentlemen, since they were first constituted in the year 1727, have, with unwearied and disinterested zeal, contributed in a very great measure to raise, and direct a spirit of industry among us, by their own example; by their experience; by adopting the experience of our neighbours; and by distributing, with great prudence, those small funds intrusted by the government to their management. For their reward they share the blessings of the industrious poor.

THE great advantage of the linen manufacture, in which point it is allowed to have the preference to the woollen, arises from the

Sect. I. ON BLEACHING. 7

the many changes which that commodity undergoes, before it comes to market; and consequently its employing many hands. But this advantage makes it more liable to suffer from ignorance, or fraud; and makes it require more care. There is no part of the manufacture on which its character so much depends, as on its management in the bleachfield. On that circumstance depend its two essential qualities, colour and strength. Of such consequence to the linen trade is that part of its progress, that I may safely venture to affirm, without assuming any title to the spirit of prophecy, that the linen manufacture of *Ireland*, from this cause alone, will, nay perhaps has already, come into some disrepute; and must at last suffer, if the *Irish* do not alter their method of bleaching.

WE, in this country, have generally followed a better method; but as that seems to be owing to our vicinity to *Holland*, and not to a greater knowledge in the art, we can claim no merit from it. That an art so ingenious, so difficult, depending so much

much on a nice judgment, consisting of so many different parts, and withal of such moment to these nations, should have lain so long neglected, affords matter of surprize. Those bred to this art are capable of furnishing materials, but are incapable, as it would seem, of reducing it to certain fixed principles. Some knowledge, besides what the art gives, appears necessary even to the art itself. This opens another source for the improvement of manufactures, *viz.* the consideration of those whose genius or education has led them to the study of sciences and arts, on which these manufactures, in a great measure, depend. There is no art of such extensive use as chymistry.

IF chymistry was once too wild and extravagant, it has been for many years too tame and confined. It seldom ventures further than the composition of a medicine, as if that were all the service it could be of to mankind. But chymistry is of much greater extent. It claims as its own, all changes that are carried on by fire, or dissolvents; it looks upon the operators, as entirely under

Sect. I. ON BLEACHING. 9

der its guidance; the operations to be accounted for only on its principles; and the hopes of further perfection in the art, so far as human judgment is concerned, to rest on it alone. This, and nothing less, is true chymistry; and may be called *Chemia philosophica*, or *Philosophical chymistry*, as Boyle has termed it; or *Universal chymistry*, to use Dr Shaw's expression, in distinction to the confined medical chymistry.

ALL arts, excepting those which regard the operations of the mind, may be distinguished into mechanical, chymical, or those which partake of both. The mechanical, or such as attain their ends by mechanical instruments, are few in respect of the chymical, which depend on fire and dissolvents. In the latter class, I rank cookery, tanning, dying, smelting, gilding, sugar-refining, confectionery, baking, brewing, making of salt, fermenting of wines and vinegar, the different metallurgic trades, distilling, soldering, making of starch, glass, delf ware, china ware, &c. The mixed arts, which partake somewhat of each, are,

B agriculture,

agriculture, building, printing, making of mirrors, paper, &c.

LET us take a view of the dependence which these arts have on chymistry. Dying cannot be carried on without it. The instruments with which that art works, are, quick-lime, alkaline and acid salts, solutions of tin and iron in acids, and neutral salts, as alum, sal ammoniac, and tartarus vitriolatus. Without the assistance of these salts, very few colours can be struck on either woollen, linen, or cotton; but with their assistance, all the colouring particles are separated from the water in which they are dissolved, and fixed on the surface of these bodies. The durableness of colours, and their resistance against the effects of sun and moisture, are to be explained only from the properties of these salts. In the solutions and mixtures of chymistry, many beautiful colours, which were never heard of in the art of dying, arise, are changed, or destroyed.

THE art of tanning is a regular chymical process,

Sect. I. ON BLEACHING. 11

process, not to be understood by those who are ignorant of its principles. What account can the tanner give of his first operation, steeping the hides in lime and water? The chymist will inform him, that the intention of it is not only to take off the hair, but to dissolve the oleaginous particles by the assistance of lime, that so the passages may be cleared for the next operation. The former must be at as great a loss to give a reason why he steeps his hides in water impregnated with oak bark, if the latter did not step in to his assistance, and show him, that the infusion of bark, by means of its astringent salt, dissolved by the water, hardens the animal fibres, and shuts up all their pores, so that water cannot pass through them so easily as it did before. It is he alone who can account for the different effects of the different methods of operating in making soft, bend or shamoy leather.

THE cook, while he prepares a dish of soup, is in that situation a real chymist. He operates with the same agents the chymist operates with; fire, and the dissolvent or

menstruum water ; and with the same design, to dissolve some part of the meat, and impregnate the water or dissolvent with these particles : but being ignorant of the other branches of chymistry, he does not know what parts are dissolved by the water, how these parts are compounded, in what manner they may be separated in greater quantity, or how the whole fibrous parts, nay the bones themselves, may be dissolved into a liquor. One who joined this knowledge to his practice, would certainly be a more compleat cook than what he was before.

AGRICULTURE, again, is greatly indebted to the powers of mechanics, the plough, harrow, and other instruments, for opening and pulverising the ground, in order that the plants may be able to push their roots to a greater distance, that they may take in their food. But what is that food and nourishment which is absorbed by the roots of plants, and without which it is in vain for them to extend their roots ? That question I may safely venture to affirm is only to be answered

Sect. I. ON BLEACHING. 13

answered by a chymist. It is he alone who can show the nature and properties of that vegetable food ; it is he alone who can tell how it comes there naturally. Experience indeed has learned farmers, that certain substances fructify the ground : but he, undoubtedly, will be able to produce the greatest quantity of that food in the shortest time, who knows what it is, and how produced. So true this is, that though dung is the most common compost, and has been used in all ages ; yet I may venture to affirm, that the chymist could teach the farmer many useful observations with respect to the management of dunghills. Farming can never be reduced to a regular art, till a farmer arise acquainted with chymistry.

I know no trade which is so entirely the object of chymistry as bleaching, and none that has been so little considered in that light. For what are steeping, bucking, souring, washing with soap, alternate wetting and drying, but so many processes, that are carried on by these powerful chymical agents, heat and dissolvents ? What is the
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end proposed, but the dissolving and carrying off, by the means of acid and alkaline salts, most powerful menstrooms, somewhat which gives the cloth its present colour? and what way more certain to carry off whatever is loosened, than the evaporation of water by heat, which is a species of distillation performed in the open air?

I find the most skilful bleachers understand the general theory of their art tolerably well; but being ignorant of the principles of chymistry, cannot make the proper use of this theory, or apply their knowledge to the advancement of their art. They know that alkaline salts dissolve oils, and that a fermentation is carried on by steeping, bucking, and souring; but chymistry can alone teach them, that by certain methods fermentations may either be quickened, and a great deal of time saved; or be checked, and much time lost; nay, perhaps the effect not produced.

BUT what the bleachers are most deficient in, is a knowledge of the nature and properties

Sect. I. ON BLEACHING. 15

properties of those alkaline salts, or ashes, as they call them, which they make use of. Experience has taught them, that these salts are to be used in different proportions ; but nothing less than a chymical inquiry can discover their hidden nature. If this point was once ascertained, the theory of bleaching would rest on a more certain foundation than at present. For what certain theory can be established with regard to the operation of those ashes, when we know not what those ashes are ?

BUT this is not all the advantage we expect to reap from an examination of this kind. What if these bodies are not simple alkaline salts ? For ought we know they may not, but may be a composition of different substances. And what if we discover by chymical experiments their composition ? If this happens to be the case, we may perhaps be able to make these ashes at a much cheaper rate in our own country, than what they cost us when imported from abroad. The inquiry is worthy of the utmost attention ; and if successful, cannot fail to be of great

great importance to this country. It costs, as I am told, *Great Britain and Ireland* L. 300,000 for ashes every year. It is difficult to say to what a sum that commodity may amount; nay, it is impossible to assure ourselves, that we will procure it at any price, when we are told, that the ashes were monopolized by two *Dutch* merchants three years ago, and retailed again to us at a double or triple price. Our manufactures could not have subsisted during the late war with *Spain*, unless an order of the King and council had passed, allowing the importation of *Spanish* pot-ashes. Both profit and necessity contribute to quicken our industry.

For the benefit of the linen manufacture of this country, and of our neighbouring island, whose interests appear to be the same, and ought always to be united against their common competitors in trade, I have applied what little knowledge I have in chymistry, and endeavoured to reduce the art of bleaching, hitherto variable and unsafe, to some fixed principles, that it might not depend

Sect. I. ON BLEACHING. 17

depend on opinion, or on such experience as always dies with the possessors.

WERE I to make myself acquainted with an art of which I was before entirely ignorant, I would naturally inquire into the common practice, or general method of operating in that art; and then endeavour to discover the design and reason of each operation, that I might know, whether the method generally practised was the fittest to attain the end proposed. I would certainly endeavour to get a thorough knowledge of the agents or instruments made use of in the art; what was the best way of procuring or making them at home; and what were their effects when applied in the manner that the art directs. I should at last consider the impediments which the art meets with, and the methods of removing them. This is the plan of the following disquisition. I have begun with the general methods of bleaching, and described those most approved of. An examination into each particular operation, its effects, the end proposed, and the best methods of accomplishing

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ing it, follows. The nature and composition of the different ashes used in bleaching; the method by which these salts may be made as good at home as those imported from abroad; and their natural effects, when applied to cloth, succeed. At last is considered that great impediment to bleaching, hard water; the method how the greatest degrees of it may be corrected, is shown; and, which is more useful to the bleacher, how the smallest degrees of it may be discovered, and so shunned. I have endeavoured to render the whole as useful to our linen trade as possible.

THERE is no way to promote the art of bleaching, which is entirely carried on by the operation of different bodies, but that of experiment: and that alone I have followed. Every other method of advancing the arts is now justly derided. It is indeed laborious to the undertaker, and cannot be accomplished without accuracy and length of time; it is often unpleasant to the reader. But, as the former has not deterred me from making the experiments, the latter shall
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not hinder me from narrating them as they were made. No doubt can remain when the experiment is before our eyes. I expect this of others; and, therefore, shall follow it myself.

AN attempt to reduce to a regular system, an art, in which nothing has yet appeared in any language, in which we have even no account of the common practice, must meet with some indulgence as to its faults. Curiosity first led me to pass some vacant hours in a bleachfield; and the desire of making bleaching as certain and regular as other arts, pushed me on. If the system is not entirely compleat, I have afforded, I hope, facts and experiments, which will serve as a foundation for such a superstructure. *Hippocrates*, an author equally admired for his art and eloquence, has long ago observed, “* That the design
“ and labour of science, ought to centre
“ in discovering what is yet unknown, and

Εμοι δε το μεν τι των μη ευρημενων εξευρισκειν, ο τι και ευρεθεν χρεσσον η ανεξευρετον ξυνεσιος δοκει επιθυμημα τε και εργον ειναι. Δε το τα ημεργα ες τελος εξεργαζεσθαι ωσαντως.
ΙΠΠΟΚΡΑΤΟΥΣ περι τεχνης.

“ may become, when known, useful to society ; and likewise in completing what was left by others imperfect.”

S E C T. II.

On the different methods of bleaching.

THERE is but one certain way to bring any art or science to perfection ; and that is, to give an exact detail of every incident which happens in the course of practice, and of every change brought about by the application of the agents or instruments employed in the art. It is by the history of diseases and practical cases, that medicine has arrived to its present height. It is from particular statutes and decisions, that the present system of law has been compiled. It is from a continuation of this plan, that perfection in these sciences, so far as human affairs can attain, is only to be hoped : for on these facts alone that theory, which opens a view of the whole art, can be established.

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Sect. II. ON BLEACHING. 21

IT is not surprising, then, that the art of bleaching is so imperfect. For what advances could be hoped for in an art, where there was no exact detail of the facts and circumstances, and where every thing remained a secret? It is rather surprising, that the art has not gone backwards, and been, ere this time, lost, as has already happened to several arts for want of a proper history of them. That such a fate may never happen to this art; that those who are not well acquainted with the practice, may understand what follows; that we may have the whole process before our eyes at once, and be able to divide it into its different parts, I shall endeavour to trace the great outlines of this art, and show the different methods used to bring cloth to its proper degree of whiteness.

IT was, no doubt, soon discovered, that the sun and dews, or frequent watering, were capable, in hot climates, of whitening cloth. This was certainly the most ancient practice; and is still used, as I have been told, in the *East Indies*. But colder
and

and more variable climates were obliged to substitute somewhat in the place of the heat which they wanted. Hence the use of salts in bleaching. Chance no doubt made the first discovery; but when or where these were first used, history is silent. Their use began probably in some of our northern countries. The cloth would at first be boiled in a lixive of alkaline salts, and then exposed to the influence of the sun and dews. This method is still used in the bleaching of yarn, and coarse open cloths. But in this climate it is very tedious. I tried the experiment last summer with some coarse cloth; but after it had been boiled once in a lixive, laid out wet, and exposed for four months, it had not attained even to a tolerable degree of whiteness. The summer indeed was unfavourable for the experiment, as there was much rain and little warmth. But from what I saw, I should despair of ever drawing any advantage from this method.

THE two methods of bleaching, established by a general practice, are the *Dutch*, and the

Sect. II. ON BLEACHING. 23

the *Irish*; one or other is followed at present by every bleacher. A description of each of these, is then a description of the whole practice. The *Dutch* method is that most followed for fine cloth by the skilful bleachers; while, for cheapness, they use, in the whitening of coarse cloth, the *Irish* method, or one very like it. I shall then give a short description of the facts which happen in each. The *Dutch* method is as follows.

AFTER the cloth has been sorted into parcels of an equal fineness, as near as can be judged, they are latched, linked, and then steeped. Steeping is the first operation which the cloth undergoes, and is performed in this manner. The linens are folded up, each piece distinct, and laid in a large wooden vessel; into which is thrown, blood-warm, a sufficient quantity of water, or equal parts of water and lye, which has been used to white cloth only, or water with rye meal or bran mixed with it, till the whole is thoroughly wet, and the liquor rises over all. Then a cover of wood is laid over

over the cloth, and that cover is secured with a post betwixt the boards and the joisting, to prevent the cloth from rising during the fermentation which ensues. About six hours after the cloth has been steeped in warm water, and about twelve in cold, bubbles of air arise, a pellicle is formed on the surface of the liquor, and the cloth swells when it is not pressed down. This intestine motion continues from thirty-six to forty-eight hours, according to the warmth of the weather; about which time the pellicle or scum begins to fall to the bottom. Before this precipitation happens, the cloth must be taken out; and the proper time for taking it out, is when no more air-bubbles arise. This is allowed to be the justest guide by the most experienced bleachers.

THE cloth is then taken out, well rinsed, disposed regularly by the selvage, and washed in the put-mill to carry off the loose dust. After this it is spread on the field to dry: when thoroughly dried, it is ready for bucking; which is the second operation.

BUCKING,

Sect. II. ON BLEACHING. 25

BUCKING, or the application of salts, is performed in this manner. The first or mother lye is made in a copper, which we shall suppose, for example, when full, holds 170 *Scots* gallons of water. The copper is filled three fourths full of water, which is brought to boil: just when it begins, the following proportion of ashes is put into it, *viz.* 30 lb. of blue, and as much white pearl ashes; 200 lb. of *Marcoft* ashes, (or, if they have not these, about 300 lb. of *Cashub*), 300 lb. of *Muscovy* or blanch ashes; the three last ought to be well pounded. This liquor is allowed to boil for a quarter of an hour, stirring the ashes from the bottom very often; after which the fire is taken away. The liquor must stand till it has settled, which takes at least six hours, and then it is fit for use.

OUT of their first or mother lye, the second, or that used in bucking, is made in this manner. Into another copper, holding for example 40 *Scots* gallons, are put 38 gallons of water, 2 lb. soft soap, and 2 gallons of mother lye; or, for cheapness,

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in place of the soap, when they have lye which has been used to white linen, called *white-linen lye*, they take 14 gallons of it, leaving out an equal quantity of water. This is called *bucking-lye*.

AFTER the linens are taken up from the field dry, they are set in the vat or cave, as their large vessel is called, in rows, endways, that they may be equally wet by the lye; which, made blood-warm, is now thrown on them, and the cloth is afterwards squeezed down by a man with wooden shoes. Each row undergoes the same operation, until the vessel is full, or all the cloth in it. At first the lye is put on milk-warm, and after standing a little time on the cloth, it is again let off by a cock into the bucking-copper, heated to a greater degree, and then put on the cloth again. This course is repeated for six or seven hours, and the degree of heat gradually increased, till it is at the last turn or two thrown on boiling hot. The cloth remains after this for three or four hours in the lye; after which the

Sect. II. ON BLEACHING. 27

the lye is let off, thrown away, or used in the first buckings, and the cloth goes on to another operation.

THE cloth is then carried out, generally early in the morning, spread on the grass, pinned, corded down, exposed to the sun and air, and watered for the first six hours, so often, that it never is allowed to dry. Afterwards it is allowed to lie till dry spots appear before it is watered. After seven at night it gets no more water, unless it be a very drying night. Next day in the morning and forenoon it is watered twice, or thrice if the day is very dry; but if the weather be not drying, it gets no water: after which it is taken up dry if the green is clean; if not, it is rinsed, mill-washed, and laid out to dry again, to become fit for bucking.

THIS alternate course of bucking and watering, is performed for the most part from ten to sixteen times, or more, before the linen is fit for souring; gradually increasing the strength of the lye from the first to the

middle bucking, and from that gradually decreasing it till the souring begins. The lyes in the middle buckings are generally about a third stronger than the first and last.

SOURING, or the application of acids to cloth, is the fourth operation. It is difficult to say when this operation should commence, and depends mostly on a length of experience. When the cloth has an equal colour, and is mostly freed from the sprat, or outer bark of the lint, it is then thought fit for souring; which is performed in the following manner. Into a large vat or vessel is poured such a quantity of butter-milk, or sour milk, as will sufficiently wet the first row of cloth; which is tied up in loose folds, and pressed down by two or three men bare-footed. If the milk is thick, about an eighth of water is added to it; if thin, no water. Sours made with bran, or rye meal, and water, are often used instead of milk, and used milk-warm. Over the first row of cloth a quantity of milk and water is thrown, to be imbibed by the second; and so it is continued till the linen to be soured

SECT. II. ON BLEACHING. 29

ed is sufficiently wet, and the liquor rises over the whole. The cloth is then kept down by covers filled with holes, and secured with a post fixed to the joist, that it may not rise. Some hours after the cloth has been in the sour, air-bubbles arise, a white scum is found on the surface, and an intestine motion goes on in the liquor. In warm weather it appears sooner, is stronger, and ends sooner, than in cold weather. Just before this fermentation, which lasts five or six days, is finished, at which time the scum falls down, the cloth should be taken out, rinsed, mill-washed, and delivered to the women to be washed with soap and water,

WASHING with soap and water, is the fifth operation; and is performed thus. Two women are placed opposite at each tub, which is made of very thick staves, so that the edges, which slope inwards, are about four inches in thickness. A small vessel full of warm water is placed in each tub. The cloth is folded so that the selvage may be first rubbed with soap and warm water length-

length-ways, till it is sufficiently impregnated with it. In this manner all the parcel is rubbed with soap, and afterwards carried to be bucked.

THE lye now used has no soap in it, except what it gets from the cloth; and is equal in strength to the strongest formerly used, or rather stronger, because the cloth is now put in wet. From the former operation these lyes are gradually made stronger, till the cloth seems of an uniform white, nor any darkness or brown colour appears in its ground. After this the lye is more speedily weakened than it was increased; so that the last which the cloth gets, is weaker than any it got before.

BUT the management of sours is different; for they are used strongest at first, and decreased so in strength, that the last sour, considering the cloth is then always taken up wet, may be reckoned to contain three fourths of water.

FROM the bucking it goes to the watering,
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Sect. II. ON BLEACHING. 31

ing, as formerly, observing only to overlap the selvages, and tye it down with cords, that it may not tear; then it returns to the four, milling, washing, bucking, and watering again. These operations succeed one another alternately till the cloth is whitened; at which time it is blued, starched, and dried.

THIS is the method used in the whitening our fine cloths. The following is the method used in the whitening of the coarse.

HAVING sorted the cloths according to their quality, they are steeped in the same manner as the fine, rinsed, washed in the mill, and dried before boiling.

IN this process, boiling supplies the place of bucking, as it takes less time, and consequently is thought cheapest. It is done in the following manner: 200 lb. *Cashub* ashes, 100 lb. white *Muscovy*, and 30 lb. pearl ashes, boiled in 105 *Scots* gallons of water for a quarter of an hour, as in the process for the fine cloth, makes the mother or first lye.

lye. The cloth-boiler is then to be filled two thirds full with water and mother lye, about nine parts of the former to one of the latter; so that the lye used for boiling the coarse cloth, is about a third weaker than that used in bucking the fine. Such a quantity of cloth is put into the foregoing quantity of lye, when cold, as can be well covered by it. The lye is brought gradually to the boil, and kept boiling for two hours; the cloth being fixed down all the time, that it does not rise above the liquor. The cloth is then taken out, spread on the field, and watered, as mentioned before in the fine cloth.

As the salts of the lye are not exhausted by this boiling, the same is continued to be used all that day, adding, at each boiling, so much of the mother lye as will bring it to the same strength as at first. The lye by boiling loses in quantity somewhat betwixt a third and a fourth; and they reckon that in strength it loses about a half, because they find in practice, that adding to it half its former strength in fresh lye, has the same effect

Sect. II. ON BLEACHING. 33

effect on cloth. Therefore some fresh lye, containing a fourth part of the water, and the half of the strength of the first lye, makes the second boiler, as they imagine, equal in strength to the first. To the third boiler they add somewhat more than the former proportion, and go on still increasing gradually to the fourth and fifth, which is as much as can be done in a day. The boiler is then cleaned, and next day they begin with fresh lye. These additions of fresh lye ought always to be made by the master bleacher, as it requires judgment to bring succeeding lyes to the same strength as the first.

WHEN the cloth comes to get the second boiling, the lye should be a little stronger, about a thirtieth part, and the deficiencies made up in the same proportion. For six or seven boilings, or fewer, if the cloth be thin, the lye is increased in this way, and then gradually diminished till the cloth is fit for souring. The whitest cloth ought always to be boiled first, that it may not be hurt by what goes before.

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IN this process, if the cloth cannot be got dry for boiling, business does not stop as in the fine; for after the coarse has dreeped on racks made for the purpose, it is boiled, making the lye strong in proportion to the water in the cloth.

THE common method of fouring coarse linen, is, to mix some warm water and bran in the vat; then put a layer of cloth; then more bran, water, and cloth; and so on, till the cave is full. The whole is tramped with mens feet, and fixed as in the former process. 1000 yards of cloth, yard-broad, require betwixt 4 and 6 pecks of bran. The cloth generally lies about three nights and two days in the four. Others prepare their four twenty-four hours before, by mixing the bran with warm water in a separate vessel; and before pouring it on the cloth, they dilute it with a sufficient quantity of water. After the cloth is taken from the four, it ought to be well washed and rinsed again. It is then given to men to be well soaped on a table, and afterwards rubbed betwixt the rubbing-boards. When it comes

Sect. II. ON BLEACHING. 35

comes from them, it should be well milled, and warm water poured on it all the time, if conveniency will allow of it. Two or three of these rubbings are sufficient, and the cloth very seldom requires more.

THE lye, after the souring begins, is decreased in strength by degrees, and three boilings after that are commonly sufficient to finish the cloth. Afterwards it is starched, blued, dried, and bittled in a machine made for that purpose, which supplies the place of a calendar, and is preferred by many to it.

THIS method used in the bleaching of our coarse cloths, is very like that practised in *Ireland* for both fine and coarse. The only material difference is, that there the bleachers use no other ashes but the kelp or *Cashub*. A lye is drawn from the former by cold water, which dissolves the salts, and not the sulphureous particles of the kelp ashes. This lye is used till the cloth is half whitened, and then they lay aside the kelp lye for one made of *Cashub* ashes. I am

told that their most skilful bleachers have laid aside the use of the kelp ashes.

THUS I have given a short sketch of the modern, and most approved practice of bleaching; a sketch sufficient to conduct those who know a little, though not designed to instruct those who are entirely ignorant. The practice is, no doubt, capable of great improvements. Some are afterwards attempted; others will be discovered by time. It is our business to forward those discoveries, and to open the speediest way for attaining and divulging them.

PART

PART II.

SECT. I.

Steeping.

IN the preceding history of bleaching, we may observe, that it naturally divides itself into several different branches or parts, all tending to give linen the degree of whiteness required. How they effectuate that, comes next under our consideration. If we can settle this question, we shall be able to discover where the present practice succeeds, and where it fails; we shall be able to settle principles, by which the art may receive further improvement; we shall reduce it to a regular science.

THE general process of bleaching divides itself into these different parts. 1. Steeping and milling. 2. Bucking and boiling. 3. Alternate watering and drying. 4. Souring. 5. Rubbing with soap and warm water, starching, and bluing. We shall

shall treat of these different parts in their order.

GREEN linen, in the different changes which it has undergone before it arrives at that state, contracts a great foulness. This is chiefly communicated to it by the dressing composed of tallow and sowen, which is a kind of flummery made of bran, flour, or oat-meal seeds. The first thing to be done in the bleachfield, is to take off all that filth which is foreign to the flax, would blunt the future action of the salts, and might, in unskilful hands, be fixed in the cloth. This is the design of steeping.

To accomplish this end, the cloth is laid to steep, or macerate, as chymists call it, in blood-warm water. A smaller degree of heat would not dissolve the dressing so soon; and a greater might coagulate and fix, as will afterwards appear, in the body of the linen, those particles which we design to carry off. In a few hours the dressing made use of in weaving is dissolved, mixed with the water; and as it had acquired some

some degree of acidity, before application, it becomes a species of ferment. Each ferment promotes its own particular species of fermentation, or intestine motion; the putrid ferment sets in motion the putrefactive fermentation; the vinous ferment gives rise to the vinous fermentation; and the acid ferment to the acetous fermentation. That there is a real fermentation going on in steeping, one must be soon convinced, who attends to the air-bubbles which immediately begin to arise, to the scum which gathers on the surface, and to the intestine motion, and swelling of the whole liquor. That it must be the acetous fermentation, appears from this, that the vegetable particles already in part soured, must first undergo this process.

THE effect of all fermentations is to set the liquor in motion; to raise in it a degree of heat; and to emit air-bubbles, which, by carrying up some of the light oleaginous particles along with them, produce a scum. But as the dressing is in small quantity in proportion to the water, these effects are gentle and slow. The acid salts are no sooner

sooner separated, by the acetous fermentation, from the absorbent earth, which made them not perceptible to the tongue in their former state, than they are united to the oily particles of the tallow, which likewise adhere superficially, dissolve them, and render them, in some degree, miscible with water. In this state they are soon washed off by the intestine motion of the liquor. The consequence of this operation is, that the cloth comes out freed in a great measure from its superficial dirt; and more pliant and soft than what it was.

WHENEVER this intestine motion is pretty much abated, and before the scum subsides, bleachers take out their cloth. The scum, when no more air-bubbles rise to support it, separates, and falls down; and would again communicate to the cloth great part of the filth, when the design of this operation was to carry it off. But a longer stay would be attended with a much greater disadvantage. The putrid follows close upon the acetous fermentation: when the latter ends, the former begins. Were this to take place,

SECT. I. ON BLEACHING. 41

place in any considerable degree, it would render the cloth black and tender, as we shall have occasion afterwards to show. Bleachers cannot be too careful in this article.

THE first question that arises to be determined on these principles, is, What is the properest liquor for steeping cloth? Those used by bleachers are plain water; white-linen lye and water, equal parts; and rye meal or bran mixed with water. They always make use of lye when they have it; a proof that they think it the best. They say it ferments most. Were that really true, I would think the reason sufficient. But there may be a deception in the case. That lye is impregnated with much foulness, which by rising to the surface may make a thicker scum, produce more air-bubbles, and give the appearance of a stronger fermentation. The alkaline salts, which make part of its composition, will attract the acid salts generated by the fermentation, and put a stop to their junction with the oils. In this view it may do harm. On the other hand, if the alkaline salts in it

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are not compleatly saturated, they may be of use in uniting with, and carrying off the greasy particles of the tallow.

SUCH opposite and unsatisfactory views are the common result of theory, when we rely entirely upon it for a decision. But shall we rest this important question on no better footing than this? Can we find no certain criterion to judge of the properest liquor for steeping linen? The design of the operation will afford us one. The end proposed by it is to loosen and carry off the superficial foulness of the cloth. That liquor then which carries off most of it, and makes the cloth lightest, must be the properest. Let us, by this test, try these different liquors.

Exp. 1. June 25. A web was cut thro' the middle into two pieces; one half of the piece, weighing 4 lb. 1 oz. was steeped in milk-warm water; the other half, weighing half an ounce more, was steeped in old lye and water, equal parts, and of an equal degree of heat with the former.

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SECT. I. ON BLEACHING. 43

There was some little fermentation in the former, but none in the latter. They were taken out on the 26th, at eleven of the clock in the forenoon, and dried. Each of the pieces now weighed 3 lb. $9\frac{1}{2}$ oz.: so that the old lye, by this experiment, appears better for cleaning cloth than plain water, as the former takes out about an eighth part more than the latter.

THAT I might compare the effects of bran with those of old lye,

Exp. 2. I cut a web into two pieces, and put one part, weighing 5 lb. 1 oz. into bran and warm water; the other, weighing 5 lb. was put into a mixture of old lye and warm water, a third of the former to two thirds of the latter. They lay forty-eight hours in these liquors; during which time there was little or no fermentation in the old lye, but a considerable degree in the bran and water. When dried, the former piece weighed 4 lb. $13\frac{1}{2}$ oz. the latter 4 lb. 11 oz. That in the bran and water had lost but $3\frac{1}{2}$ oz. but that in the old lye had lost 5 oz.

THAT I might make the same trial on greater quantities of cloth,

Exp. 3. I took six pieces of cloth, nearly of the same fineness, and containing twenty-five yards each. Two of these, weighing 20 lb. 1 oz. were steeped in old lye; other two, weighing 18 lb. 15 oz. in bran and water; the remaining two, weighing 19 lb. 13 oz. in plain water. All these liquors were of an equal degree of warmth. These lay for forty-eight hours, in the month of *June*; during which time the fermentation was strongest in the bran and water, next in the plain water, and weakest in the lye. Taken out and dried, the first weighed 18 lb. 12½ oz. and so had lost 1 lb. 4½ oz.; the second weighed 17 lb. 11 oz. and so had lost 1 lb. 4 oz.; the last weighed 17 lb. 12 oz. and so had lost 1 lb. 7 oz. The bran and water, in this last experiment, appears to have had a better effect than the old lye; and the plain water than either. This question, therefore, still remains undecided. The only method, however, is pointed out, and a multiplicity

SECT. II. ON BLEACHING. 45

city of experiments must be tried, before we can determine what liquor is in general best.

AFTER steeping, the cloth is carried to the putstock-mill, to be freed of all its loose foulness. There can be nothing contrived so effectual to answer the purpose as this mill. Its motion is easy, regular, and safe. While it presses gently, it turns the cloth; which is continually washed with a stream of water. Care must be taken that no water be detained in the folds of the linen, otherwise that part may be damaged.

S E C T. II.

Bucking and boiling.

THIS is the most important operation of the whole process, and deserves a thorough examination. Its design is to loosen, and carry off, by the help of alkaline lixives or lyes, that particular substance in cloth, which is the cause of its brown-colour.

colour. The salts, or ashes, as the bleachers call them, used in the composition of the lye, demand, for many reasons, a particular scrutiny; and therefore I shall examine them afterwards by themselves.

THESE ashes, the pearl excepted, ought to be well pounded, before they are put into the copper; for the *Marcoft* and *Cashub* are very hard, and with some difficulty yield their salts. As these two last contain a very considerable proportion of a real sulphureous matter, which must in some degree tinge white cloth; and as this is dissolved much more by boiling, than by the inferior degrees of heat, while the salts may be as well extracted by the latter, I would propose that the water should never be brought to boil, and should be continued for some time longer under that degree of heat. The pearl ashes should never be put in till near the end, as they are easily dissolved in water.

IF the salts were always of an equal strength, the same quantities would make

SECT. II. ON BLEACHING. 47

a lye equally strong: but they are not. Salts of the same name differ very much from one another. The *Muscovy* ashes are turning weaker every day, as every bleacher must have observed, till at last they turn quite effete. A decoction from them, when new, must differ very much from one when they have been long kept. Hence a necessity of some exact criterion to discover when lyes are of an equal strength. The taste cannot serve, as that is so variable, cannot be described to another, and is blunted by repeated trials. The proof-ball will serve the purpose of the bleach-field sufficiently; and, by discovering the specific gravity, will show the quantity of alkaline salts dissolved. But it cannot show the dangerous qualities of these salts; for the less caustic and less heavy this liquor is, the more dangerous and corrosive it may be for the cloth.

THIS must appear a paradox at present, but will afterwards be proved by many experiments. The third lye, which they draw from these materials by an infusion
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of cold water, where I could plainly taste the lime, appears to me more dangerous than the first. The second lye, which they extract from the same ashes, and which is reckoned about a third in strength, when compared to the first, must be of the same nature; nor do I think it should be used without an addition of pearl ashes, which will correct it.

It is taken for a general rule, That the solution of any body in its menstruum is equally diffused through the whole liquor. The bleachers depending on this, use equal quantities of the top and bottom of their lye, when once clear and settled; taking it for granted, that there is an equal quantity of salts in equal quantities of the lye. But if there is not, the mistake may be of fatal consequence; as the lye may be in some places stronger than what the cloth can with safety bear. That general law of solution must have taken its rise from particular experiments, and not from reasoning. Whether a sufficient number of experiments have been tried to ascertain this point,

Sect. II. ON BLEACHING. 49

point, and to establish an undoubted general rule, may be called in question.

BUT when I had discovered that lime makes part of the dissolved substance, and reflected how long its grosser parts will continue suspended in water, there appeared stronger reasons for my suspecting that this rule, though it may be pretty general, does not take place here; at least it is worth the pursuit of experiment.

Exp. 4. I weighed at the bleachfield a piece of glass in some cold lye, after it had been boiled, stood for two days, and about the fourth part of it had been used. The glass weighed 3 drachms $1\frac{1}{2}$ grains in the lye, and 3 drachms $7\frac{1}{2}$ grains in river-water. The same glass weighed in the same lye, when almost all used, 2 grains less than it had done before. This shows, that the last of the lye contained a third more of the dissolved body; and, consequently, was a third stronger than the first of the lye.

As this might, perhaps, be owing to a
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continuation of the solution of the salts, I repeated the experiment in a different way.

Exp. 5. I took from the surface some of the lye, after the salts were dissolved, and the liquor was become clear. At the same time I immersed a bottle, fixed to a long stick, so near the bottom, as not to raise the ashes there, and, by pulling out the cork by a string, filled the bottle full of the lye near the bottom. The glass weighed in river-water 3 drachms $38\frac{1}{2}$ grains; in the lye taken from the surface 3 drachms $34\frac{1}{2}$ grains; and in the lye taken from the bottom 3 drachms $31\frac{1}{2}$ grains. This experiment shows, that the lye at the bottom was, in this case, $\frac{3}{4}$ stronger than the lye at the surface.

At other times when I tried the same experiment, I found no difference in the specific gravity; and, therefore, I leave it as a question yet doubtful, though deserving to be ascertained by those who have an opportunity of doing it. As the lye stands continually on the ashes, there can be

Sect. II. ON BLEACHING. 51

be no doubt but what is used last must be stronger than the first. I would, therefore, recommend, to general practice, the method used by Mr *John Christie*, who draws off the lye, after it has settled, into a second receptacle, and leaves the ashes behind. By this means it never can turn stronger; and he has it in his power to mix the top and bottom, which cannot be done so long as it stands on the ashes.

HAVING considered the lye, let us next inquire how it acts. On this inquiry depends almost the whole theory of bleaching, as its action on cloth is, at least in this country, absolutely necessary. We shall see, in some experiments which follow on the natural effects of these ashes, that one effect they have on cloth, is the diminishing of its weight; and that their whitening power is, generally, in proportion to their weakening power. Hence arises a probability, that these lyes act by removing somewhat from the cloth, and that the loss of this substance is the cause of whiteness. This appears yet plainer, when the buck-

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ing, which lasts from *Saturday* night to *Monday* morning, is attended to. There I have seen evident signs of a solution going on from the quantity of air-bubbles arising, when the liquor was almost cold.

THERE are various and different opinions with regard to the operation of these salts: That they act by altering the external texture of the cloth, or by separating the mucilaginous parts from the rest, or by extracting the oil which is laid up in the cells of the plant. The last is the general opinion, or rather conjecture, for none of them deserves any better name; but we may venture to affirm, that it is so without any better title to pre-eminence, than what the others have. Alkaline salts dissolve oils, therefore these salts dissolve the cellular oil of the cloth, is all the foundation which this theory has to rest on; too slight, when unsupported by experiment, to be relied on.

IN settling this question, we shall not only fix the theory of bleaching, but likewise

wife that of the lithontriptic quality of medicines, whose effects on the human calculus are observed to be the same as the effects of these materials on cloth. The solvents of the stone, and the bleaching materials, are the same. They produce similar effects on both; such as diminution of weight, a white colour, the generation of much elastic air, and at last a dissolution or separation of parts. But their method of acting has not yet been ascertained by any certain and conclusive experiment. Let us then bring the question, if we can, to that test.

WAX is whitened by being exposed to the influence of the sun, air, and moisture. A discovery of the changes made on it by bleaching, may throw a light upon the question.

Exp. 6. Six drachms of wax were sliced down, exposed on a south window, *September* 10. and watered. That day being clear and warm, bleached the wax more than all the following. It seemed to me to
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whiten quicker when it had no water thrown on it, than when it had. *Sept.* 15. it was very white, and 1 drachm 3 grains lighter. $3\frac{1}{2}$ drachms of this bleached wax, and as much of unbleached, taken from the same piece, were made into two candles of the same length and thickness, having cotton wicks of the same kind. The bleached candle burned one hour thirty-three minutes; the unbleached three minutes longer. The former run down four times, the latter never. The former had an obscure light and dull flame; the latter had a clear pleasant one, of a blue colour at the bottom. The former when burning seemed to have its wick thicker, and its flame nearer the wax, than the latter. The former was brittle, the latter not. It plainly appears from these facts, that the unbleached wax was more inflammable than the bleached; and that the latter had lost so much of an inflammable substance, as it had lost in weight; and consequently the substance lost in bleaching of wax is the oily part. Dr *Hales* observes, that wax in distillation affords an inflammable vapour.

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As I had not an opportunity of repeating the former experiment, I do not look on it as entirely conclusive; for it is possible that some of the dust, flying about in the air, might have mixed with the bleached wax, and so have rendered it less inflammable. Nor do I think the analogical reasoning from wax to linen without objections. Let us try then if we cannot procure the substance extracted from the cloth, show it to the eye, and examine its different properties. The proper place to find it, is in a lye already used, and fully impregnated with these colouring particles.

Exp. 7. I got in the bleachfield some lye, which had been used all that day for boiling coarse linen, which was tolerably white, and had been twice boiled before. There could be no dressing remaining in these webs. No soap had ever touched that parcel; nor do they mix soap with the lye used for coarse cloth. Some of this impregnated lye was evaporated, and left a dark-coloured matter behind. This substance felt oily betwixt the fingers, but
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would not lather in water as soap does. It deflagrated with nitre in fusion, and afforded a tincture to spirit of wine. By this experiment the salts seem to have an oily inflammable substance joined with them.

COULD we separate this colouring substance from these salts, and exhibit it by itself, so that it might become the object of experiment, the question would be soon decided. Here chymistry lends us its assistance. Whatever has a stronger affinity or attraction to the salts with which it is joined, than this substance has, must set it at liberty, and make it visible. Acids attract alkaline salt from all other bodies; and therefore will serve our purpose.

Exp. 8. Into a quantity of the impregnated lye mentioned in the former experiment, I poured in oil of vitriol. Some bubbles of air arose, an intestine motion was to be perceived, and the liquor changed its colour from a dark to a turbid white. It curdled like a solution of soap, and a scum soon gathered on the surface, about half an inch

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Sect. II. ON BLEACHING. 57

in thickness, the deepness of the liquor not being above six inches. What was below was now pretty clear. A great deal of the same matter lay in the bottom; and I observed, that the substance on the surface was precipitated, and showed itself heavier than water, when the particles of air, attached to it in great plenty, were dispelled by heat. This substance was in colour darker than the cloth which had been boiled in it.

I procured a considerable quantity of it by skimming it off. When I tried to mix it with water, it always fell to the bottom. When dried by the air, it diminished very much in its size, and turned as black as a coal. In this state it deflagrated strongly with nitre in fusion; gave a strong tincture to spirit of wine; and when put on a red-hot iron, burnt very slowly, as if it contained a heavy ponderous oil; and left some earth behind.

FROM the inflammability of this substance, its rejecting of water, and dissolving in spirit of wine, we discover its oleaginous na-

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ture; but from its great specific gravity we see, that it differs very much from the expressed or cellular oil of vegetables; and yet more from their mucilage. That it dissolves in spirit of wine, is not a certain argument of its differing from expressed oils; because these, when joined to alkaline salts, and recovered again by acids, become soluble in spirit of wine. The quantity of earthy powder left behind after burning, shows that it contains many of the solid particles of the flax. The substance extracted from cloth by alkaline lyes appears then to be a composition of a heavy oil, and the solid earthy particles of the flax. Whether this heavy oil differs originally in the plant, from the oil expressed from its cells, or whether the latter is converted into the former, by losing in solution great part of its air, I cannot determine; nor is it necessary. At present they seem widely different.

In what manner these salts act so as to dissolve the oils, and detach the solid particles, whether from a certain polarity, as

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Sect. II. ON BLEACHING. 59

Dr *Hales* imagines, or from other causes, of which the imagination can suggest many, is not allowed us certainly to know. The speculation is too subtle to admit of experiments, and too uncertain to be trusted to without these. It is enough for us to know on what principles in the cloth these salts operate. We see evidently how much cloth must be weakened by an improper use of these salts, as we find the solid particles themselves are separated.

It is necessary that cloth should be dry before bucking, that the salts may enter into the body of the cloth along with the water; for they will not enter in such quantity, if it be wet; and by acting too powerfully on the external threads, may endanger them.

THE degree of heat is a very material circumstance in this operation. As the action of the salts is always in proportion to the heat, it would appear more proper to begin with a boiling heat, by which a great deal of time and labour might be saved.

The reason why this method is not followed, appears to be this. If any vegetable or vegetable substance is to be softened, and to have its juices extracted, it is found more proper to give it gentle degrees of heat at first, and to advance gradually, than to plunge it all at once in boiling water. This last degree of heat is so strong, that when applied at once to a vegetable, it hardens, instead of softening its texture. Dried vegetables are immediately put into boiling water by cooks, that these substances may preserve their green colour, which is only to be done by hindering them from turning too soft. Boiling water has the same effect on animal substances; for if salt beef is put into it, the water is kept from getting at the salts, from the outside of the beef being hardened.

BUT when we consider, how much of an oily substance there is in the cloth, especially at first, which will for some time keep off the water, and how the twisting of the threads, and closeness of the texture, hinders the water from penetrating, we shall

Sect. II. ON BLEACHING. 61

shall find, that if boiling water were put on it at once, the cloth might be liable, in several parts, to a dry heat, which would be much worse than a wet one. That the lyes have not access to all parts of the cloth, at first, appears plainly from this, That when it has lain, after the first bucking, till all the lyes are washed out, it is as black, in some parts, as when it was steeped. This must be owing to the discharge of the colouring particles from those places to which the lye has access, and to their remaining where it has not. It would seem adviseable, then, in the first bucking or two, when the cloth is foul, to use the lye considerably below the boiling point; that by this soaking, or maceration, the foulness may be entirely discharged, and the cloth quite opened for the speedy reception of the boiling lye in the buckings which follow.

THE lyes should likewise be weakest in the first buckings, because then they act only on the more external parts; whereas, when the cloth is more opened, and the
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field of action is increased, the active powers ought to be so too. For this reason they are at the strongest after some fourings.

I was of opinion, that the cloth was allowed to lie too short time in the lye, and that more time on this account was consumed in the bleaching of cloth than was necessary. What confirmed my suspicions, was, that I observed the cloth, which lay in the bucking-vat from *Saturday* night to *Monday* morning, come out of a deeper colour, and when exposed to the air, became whiter, than the others of the same parcel, which had been in the lye for twelve hours only. I caused the experiment to be tried on a whole parcel every time they were bucked; and they advanced faster, and with as great safety, as other pieces which were managed in the common way. As to the effect of soap mixed with the lye, I shall have occasion afterwards to show, that it has no power in correcting the dangerous qualities of the lye.

lye. At the same time we shall discover, what is the proper corrector.

THE only thing that now remains to be considered, is, the management of the coarse cloth, where boiling is substituted in place of bucking. This species of linen cannot afford the time and labour necessary for the latter operation; and therefore they must undergo a shorter, and more active method. As the heat continues longer at the degree of boiling, the lyes used to the coarse cloth must be weaker than those used to the fine. There is not so much danger from heat in the coarse, as in the fine cloth, because the former is of a more open texture, and will allow the lye to penetrate more speedily. In the closer kinds, however, I would advise, that the first application of the salts should be made without a boiling heat.

I cannot help greatly condemning the method generally used, of boiling all the cloth of that day in the same lye. I can see no certainty of having all the lyes of the
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same strength, because neither the taste nor proof-ball can be of use here; the taste, because the oily matter sheathes the salts; the proof-ball, because there is another substance here besides salts. But I am sure of this, that so much filth, as a former experiment showed in lye often used, cannot but communicate some of itself to the cloth, and instead of advancing, retard its whiteness. It will appear afterwards, from experiments, that cloth boiled in a foul lye becomes heavier, and consequently takes in part of its foulness. If it is done for cheapness, I am not of opinion, that it will turn out so on a further examination; for the last additions of fresh lye must be blunted greatly by the foulness in the old lye; and the bleachers themselves observe, that they have not such a strong effect as the first. No lye, therefore, can with any advantage be used above twice.

S E C T. III.

Alternate watering and drying.

AFTER the cloth has been bucked, it is carried out to the field, and frequently watered for the first six hours. For if, during that time, when it is strongly impregnated with salts, it is allowed to dry, the salts approaching closer together, and, assisted by a greater degree of heat, increasing always in proportion to the driness of the cloth, act with greater force, and destroy its very texture. After this time, dry spots are allowed to appear before it gets any water. In this state I imagine it profits most, as the latter part of the evaporation comes from the more internal parts of the cloth, and will carry away most from those parts. The bleaching of the wax, in a preceding experiment, helps to convince me of this; for it seemed to whiten most when the last particles of water were going off.

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THIS continual evaporation from the surface of the cloth shows, that the design of the operation is to carry off somewhat remaining after the former process of bucking. This appears likewise from a fact known to all bleachers, that the upper side of cloth, where the evaporation is strongest, attains to a greater degree of whiteness than the under side. But it is placed beyond all doubt by the experiment in sect. 1. of part 4.; where it appears, that cloth turns much lighter by being exposed to the influence of the sun, air, and winds, even though the salts have been washed out of it.

WHAT, then, is this substance? As we have discovered in the former section, that the whitening, in the operation of bucking, depends on the extracting or loosening the heavy oil, and solid particles of the flax; it appears highly probable, that the effects of watering, and exposition to the sun, air, and winds, are produced by the evaporation of the same substance, joined to the salts, with which composite body the cloth

Sect. III. ON BLEACHING. 67

is impregnated when exposed on the field. That these salts are in a great measure carried off or destroyed, appears from the cloth's being allowed to dry without any danger, after the evaporation has gone on for some time. If we can show, that oils and salts, when joined together, are capable of being exhaled, in this manner, by the heat of the atmosphere, we shall reduce this question to a very great degree of certainty.

Exp. 9. Sept. 10. I exposed, in a south-west window, half an oz. of *Castile* soap, sliced down, and watered. *Sept. 14.* when well dried, it weighed but 3 dr. 6 gr. *Sept. 22.* it weighed 2 dr. 2 gr. *Sept. 24.* it weighed 1 dr. 50 gr. It then seemed a very little whiter; but was much more mucilaginous in its taste, and had no degree of saltiness, which it had before.

It appears, from this experiment, that soap is so volatile, when watered, and exposed to air not very warm, that it loses above the half of its weight in fourteen days.

The same must happen to the saponaceous substance, formed from the conjunction of the alkaline salts, heavy oil, and earthy particles of the flax. The whole design, then, of this operation, which, by way of pre-eminence, gets the name of *bleaching*, is to carry off, by the evaporation of water, whatever has been loosened by the former process of bucking.

AGAINST this doctrine there may be brought two objections, seemingly of great weight. It is a general opinion amongst bleachers, that linen whitens quicker in *March* and *April*, than in any other months: but as the evaporation cannot be so great at that time, as when the sun has a greater heat; hence the whitening of cloth is not in proportion to the degree of evaporation; and therefore the former cannot be owing to the latter. This objection vanishes, when we consider, that the cloth which comes first into the bleachfield, in the spring, is closely attended, having no other to interfere with it, for some time; and, as it is the whitest, gets, in the after buckings,

Sect. III. ON BLEACHING. 69

ings, the first of the lye; while the second parcel is often bucked with what has been used to the first. Were the fact true, on which the objection is founded, this would be a sufficient answer to the objection. But it appears not to be true, from an observation of Mr *John Chryslie*, That cloth laid down in the beginning of *June*, and finished in *September*, takes generally less work, and undergoes fewer operations, than what is laid down in *March*, and finished in *June*.

THE other objection is, That cloth dries much faster in windy weather than in calm sunshine; but it does not bleach so fast. This would seem to show, that the sun has some particular influence independent on evaporation. In answer to this objection, let it be considered, that it is not the evaporation from the surface, but from the more internal parts, as I said before, that is of benefit to the cloth. Now, this latter evaporation must be much stronger in sunshine than in windy weather, on account of the heat of the sun, which will make the

the cloth more open; while the coldness of windy weather must shut it up, so that the evaporation will all be from the surface. Clear sunshine, with a very little wind, is observed to be the best weather for bleaching; a convincing proof that this reasoning is just.

It would seem to follow as a corollary from this reasoning, that the number of waterings should, in general, be in proportion to the strength of the lye; for the stronger the lye is, the more there is to be evaporated; and the greater the danger, in case the cloth should be allowed to dry. But there is an exception to this general rule, arising from the consideration of another circumstance. It is observed, that cloth, when brown, dries sooner, than when it becomes whiter, arising from the closeness and oiliness, which it then has, not allowing the water a free passage. Perhaps that colour may retain a greater degree of heat, and in that way assist a very little. Cloth, therefore, after the first buckings, must

Sect. III. ON BLEACHING. 71

must be more carefully watered than after the last.

IT follows likewise from this reasoning, that the soil of the bleachfield should be gravelly or sandy, that the water may pass quickly through it, and that the heat may be increased by the reflection of the soil: for the success of this operation depends on the mutual action of heat and evaporation. It is likewise necessary that the water should be light, soft, and free from mud or dirt, which, not being able to rise along with the water, must remain behind. When there is much of this, it becomes necessary to rinse the cloth in water, and then give it a milling, to take out the dirt; else it would be fixed in the cloth by the following bucking, as it is not soluble by the lye.

THIS operation has more attributed to it by bleachers than it can justly claim. The cloth appears, even to the eye, to whiten under these alternate waterings and dryings; and these, naturally, get the honour of it, when it more properly belongs to the former

former operation. Here lies the fallacy. Alkaline salts give a very high colour to the decoctions, or infusions of vegetables. This is probably owing to the solution of the oleaginous colouring particles of the plant; which particles, being opened and separated by the salts, occupy a greater space, and give a deep colour to the liquor. The cloth participates of the liquor and colour. Hence bleachers always judge of the goodness of the bucking by the deepness of its colour. The rule, in general, is good. I observe, that in those buckings which continue from the *Saturday* night to the *Monday* morning, the cloth has always the deepest colour. When that cloth has been exposed some hours to the influence of the air, these colouring particles, which are but loosely attached to it, are evaporated, and the linen appears of a brighter colour. This operation does no more than complete what the former had almost finished. If its own merit were thoroughly known, there would be no occasion to attribute that of another operation to it. Thread, and open cloths, such as diaper, may be reduced

Sect. III. ON BLEACHING. 73

ced to a great degree of whiteness, after one bucking, by it alone. No cloth, as would appear, can attain to a bright whiteness without it.

SINCE the only advantage of watering is the removal of the salts, and what they have dissolved, might we not effectuate this by some cheaper, and more certain method? For it occupies many hands; and must depend, altogether, on the uncertainty of the weather; so that, in the beginning of the season, the bleacher is often obliged to repeat his buckings without bleaching. We might take out the alkaline salts by acids; but then the other substance would be left alone in the cloth, nor would any washing be able to remove it. Mill-washing appears a more probable method of taking out both salts and oils; and it would seem that this might, in a great measure, supply the place of watering; but upon trial it does not succeed. Two parcels of linen were managed equally in every other respect, except in this, That one was watered, and exposed to the influence of the

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air, and the other was only mill-washed. This method was followed until they were fit for souring. The cloth which had been mill-washed, had a remarkable green colour, and did not recover the bright colour of the pieces managed in the common way, until it had been treated like them for a fortnight. The green colour was certainly owing to a precipitation of the sulphureous particles, with which the lye is impregnated, upon the surface of the cloth; owing to the salts being washed off more speedily than the sulphur, to which they are united in the lye. The attachment betwixt these two bodies, we know, is very loose, and the separation easily made. Evaporation, then, alone is sufficient to carry off these sulphureous particles.

S E C T. IV.

Souring.

IT is well known to all chymists, and will afterwards appear, that alkaline salts are convertible, by different methods, into absorbent earths. Frequent solution in
water,

Sect. IV. ON BLEACHING. 75

water, and evaporation of it again, is one of these. This transmutation, then, of these salts, which are not volatilised, or washed away, must be continually going on in the cloth under these alternate waterings and dryings of the former process. Not much, indeed, after the first two or three buckings; because the salts, not having entered deep into the cloth, are easily washed off, or evaporated. But when they penetrate into the very composition of the last and minutest fibres, of which the first vessels are made, they find greater difficulty of escaping again, and must be more subject to this transmutation. But if we consider the bleaching ashes as a composition of lime and alkaline salts, we must discover a fresh fund for the deposition of this absorbent earth. The common caustic, a composition of this very kind, soon converts itself, if exposed to the open air, into a harmless earthy powder.

FREQUENT buckings and bleachings load the cloth with this substance. It becomes, then, necessary to take it out. No wash-

ing can do that, because earth is not soluble in water. Nothing but acids can remove it. These are attracted by the absorbent earth, join themselves to it, and compose a kind of neutral imperfect salt, which is soluble in water; and therefore easily washed out of the cloth. The acid liquors commonly used are butter milk, which is reckoned the best; sour milk; infusions of bran, rye-meal, &c. kept for some days till they sour. Sour whey is thought to give the cloth a yellow colour.

THE linen ought to be dried before it is put in the sour, that the acid particles may penetrate, along with the watery, thro' the whole. A few hours after it has been there, air-bubbles arise, the liquor swells, and a thick scum is formed; manifest signs of a fermentation. The following experiment shows the degree of heat which attends it.

Exp. 10. May 25. I put a thermometer of *Fahrenheit's* into some butter milk of which the bleachers were composing their sours,
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Sect. IV. ON BLEACHING. 77

and which stood in a vat adjoining to another, where the milk was the same, and the souring process had been going on for two days. After the thermometer had been twenty minutes in the butter milk, the mercury stood at 64 degrees. In the souring vat it rose to 68 degrees. An increase of 4 degrees shows a pretty brisk intestine motion.

To what are all these effects owing? To the acetous fermentation going on in those vegetable liquors, whose acids, extricating themselves, produce heat, intestine motion, and air-bubbles. As the change is slow, the process takes five or six days before it is finished. During this time the acid particles are continually uniting themselves to the absorbent earth in the cloth. That this fermentation goes on in the liquor alone, appears from this consideration, that the same effects, *viz.* air-bubbles, and scum, are to be seen in the butter milk alone. The only effect, then, it has, so far as I can see, is, by the small degree of heat, and intestine motion, which attend it,

it, to assist the junction of the acid and absorbent particles. We shall presently see, that this process may be carried on, to as great advantage, without any fermentation; and therefore it appears not absolutely necessary.

WHEN these absorbent particles are fully saturated, the remaining acids may unite with, and have some small effect in extracting the colouring particles. This appears from the two following experiments.

Exp. 11. Sept. 20. A piece of cloth which had been steeped, weighing $41\frac{1}{2}$ gr. was put into a half-pound of butter milk, whigged, and well soured, by a mixture of water, and by boiling. *Sept. 24.* when taken out, and washed in water, it appeared a very little whiter. The mineral acids, as will appear afterwards, whiten cloth, even though they are very much diluted,

JUST before the acetous fermentation is finished, the cloth should be taken out; otherwise the scum will fall down, and lodge
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Sect. IV. ON BLEACHING. 79

in the cloth, and the putrefaction, which then begins, will weaken it. ~ This appears from the following experiment.

Exp. 12. Sept. 16. A piece of cloth weighing 42 gr. was laid in butter milk unwhigged. *Nov. 15.* the milk had a putrified smell. The cloth was a little whiter, but very tender; and weighed, when well washed in warm water, and dried, 40 gr.

ALL the fours made of bran, rye-meal, &c. ought to be prepared before use; for by this means so much time will be saved. Besides, when the water is poured upon the cloth, and bran, as is done in the management of coarse cloth, the linen is not in a better situation than if it had been taken up wet from the field; and by this means the acid particles cannot penetrate so deep. Again, this method of mixing the bran with the cloth, may be attended with yet worse consequences. All vegetable substances, when much pressed, fall into the putrescent, and not the acetous fermentation. This must, and does happen to the bran pressed betwixt

betwixt the different layers of the linen. I had occasion to see it one day, in a bleach-field, when they were drawing a parcel of coarse cloth soured in this manner. The bran had attained to a considerable degree of putrefaction, but the liquor had not. The cloth, immediately above and below this putrid bran, must have been weakened by it. For these obvious reasons I would propose, that all the sours should be prepared before the cloth is steeped in them; and that none of the bran, or meal, should be mixed with the cloth.

THE sours are used strongest at first, and gradually weakened till the cloth has attained to its whiteness. In the first fourings, there is more of the earthy matter in the cloth, from the many buckings it has undergone, than what there can be afterwards. As the quantity of this matter decreases, so should the strength of the sour. I am not, however, of opinion, that there is the least danger at any time, from too strong a sour. Why they should not be used somewhat

SECT. IV. ON BLEACHING. 81

what sooner than they are, I could never see any reason.

WHAT is most wanted in this operation, is, a more expeditious and cheaper method of obtaining the same end. As it takes five or six days, it retards the whitening of the cloth considerably; and as bleachers are obliged to send for milk to a great distance, it becomes very dear. This last consideration makes them keep it so long, that, when used, it can have no good effect; perhaps it may have a bad.

THERE is one consideration that may lead us to shorten the time. It is observed, that the souring process is sooner finished in warm than in cold weather. Heat quickens the fermentation, by aiding the intestine motion. I would propose, then, that the vats should not be buried in the ground, as they always are, which must keep them cold; and that there should be pipes along the walls of the room, to give it that degree of heat, which, on trial, may be found to answer best. I am of opinion, that there

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are few days in summer so hot as is necessary; and that the beginning and end of the season, is by very much too cold. That this is no ideal scheme, the following fact is a sufficient proof. There are two vats in *Salton* bleachfield, adjoining to a partition-wall, at the back of which there is a kitchen-fire. In these vats the souring process is finished in three days, whereas it lasts five or six days in the others placed round the same room.

THIS improvement, though it shortens the time of souring a very little, yet is no remedy against the scarcity and dearth of milk sours. Such a liquor as would serve our purpose, must be found either among the vegetable acids, which have no further fermentation to undergo, or among the mineral acids. The former are a large class, and contain within themselves many different species, such as the acid juice of several plants, vinegars made of fermented liquors, and acid salts called *tartars*. But there is one objection against all these vegetable acids: They all contain, along with the acid,

SECT. IV. ON BLEACHING. 83

a great quantity of oleaginous particles, which would not fail to discolour the cloth. Besides, the demand of the bleachfields would raise their price too high.

THE mineral acids have neither of these objections. They are exceedingly cheap, and contain no oil, though many chymists have asserted that they did. I will freely own, that, at first, I had no great opinion of their success; from two reasons; their want of all fermentation, which I then looked on as necessary; and their extreme corrosiveness. But the experience of two different summers, in two different bleachfields, has convinced me, that they will answer all the purposes of the milk and bran sours; nay, in several respects, be much preferable to them. I have seen many pieces of fine cloth, which had no other sours, but those of vitriol, and were as white and strong as those bleached in the common way. I have cut several webs through the middle, and bleached one half with milk, and the other with vitriol, gave both the

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same number of operations, and the latter were as white and strong as the former.

THE method, in which it has been hitherto used, is this. The proportion of the oil of vitriol to the water, with which it is diluted, is half an ounce, or at most three quarters of the former, to a gallon of the latter. As the milk fours are diminished in strength, so ought the vitriol fours. The whole quantity of the oil of vitriol to be used, may be first mixed with a small quantity of water, then added to the whole quantity of water, and well mixed together. The water should be milk-warm; by which means the acid particles will penetrate further, and operate sooner. The cloth should then be put dry into the liquor.

IT is observed, that this four performs its task much sooner than those of milk or bran; so that Mr *John Chrystie*, in making the trial, used to lay the milk fours twenty-four hours before the vitriol. I am of opinion, that five hours will do as much with this four, as five days with the common
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Sect. IV. ON BLEACHING. 85.

fort. But the cloth can receive no harm in allowing it to remain for some days in the sour, but rather, on the contrary, an advantage, as we shall have occasion afterwards to observe. The cloth is then taken out, well rinsed, and mill-washed in the ordinary way.

THE liquor, while the cloth lies in this sour, is less acid the second day than the first, less the third than the second, and so diminishes by degrees. At first it is clear, but by degrees a mucilaginous substance is observed to float in it, when put into a glass. This foulness increases every day. This substance extracted by the acid, is the same with what is extracted by the alkaline salts; and blunts the acidity of the former, as I have shown it does the alkalescency of the latter. This will appear more plain, when I come to show the natural effects of these acid salts on unbleached cloth. Hence the liquor loses, by degrees, its acidity. But as the acid salts do not unite so equally with oleaginous substances, as the alkaline do, the liquor is not so uniformly tinged in the

the former, as in the latter case, and the mucous substance presents itself floating in it.

It is observed, that, in the first souring, which is the strongest, the liquor, which was a pretty strong acid before the cloth was put in, immediately afterwards becomes quite vapid; a proof how very soon it performs its task. But in the following operations, as the linen advances in whiteness, the acidity continues much longer; so that in the last operations the liquor loses very little of its acidity. This happens although the first buckings, after the first sourings, are increased in strength, while the sours are diminished. There are two causes to which this is owing. The texture of the cloth is now so opened, that although the lyes are strong, the alkaline salts and absorbent earth are easily washed out; and the oleaginous particles are, in a great measure, removed, which help to blunt the acidity of the liquor.

I have heard two objections brought against

Sect. IV. ON BLEACHING. 87

gainst the use of vitriol sours. One is, That the process of souring with milk is performed by a fermentation; and as there is no fermentation in the vitriol sours, they cannot serve our purpose so well: the other, That they may hurt the texture of the cloth. The answer to the former objection is very short, That the vitriol sours operate successfully without a fermentation, as experience shows; and therefore in them a fermentation is not necessary. The same objection might be made to strike against the vegetable sours, That as the mineral acids operate without fermentation, therefore the vegetable, which ferment, will not succeed; but the truth is, that both succeed. The vegetable liquors must ferment, that their acids may be set free; but the mineral acids neither stand in need, nor are capable of any such change. This shows evidently, that all the advantage of fermentation is to disengage the acid salts, that they may exert themselves on the cloth.

As to the latter objection, That oil of vitriol,

triol, being a very corrosive body, may hurt the cloth; that will vanish likewise, when it is considered how much the vitriol is diluted with water, that the liquor is not stronger than vinegar, and that it may be safely taken into the human body. But there will remain no doubt of its safety, when I come afterwards to show, that I have kept linen in a strong sour of vitriol for many months, and that the cloth was as strong after it was taken out, as when it was put in. These experiments convinced me of its safety, before I had experience of its use in the bleachfield.

THAT it may be used with safety, much stronger than what is necessary in the bleachfield, appears from the following experiment with regard to the stamping of linen. After the linen is boiled in a lye of ashes, it is bleached for some time. After this, in order to make it receive the colour, it is steeped in a sour of water and oil of vitriol, about fifteen times stronger than that made use of in the bleachfield; for to 100 gallons of water are added two and a half

Sect. V. ON BLEACHING. 89

half of oil of vitriol. Into this quantity of liquor, made so warm as the hand can just be held in it, is put seven pieces of 28 yards each. The linen remains in it about two hours, and comes out remarkably whiter. The fine cloth often undergoes this operation twice. Nor is there any danger if the oil of vitriol is well mixed with the water. But if the two are not well mixed together, and the oil of vitriol remains, in some parts, undiluted, the cloth is corroded into holes.

LET us now take a view of the advantages which the vitriol fours must have over the milk. The latter is full of oleaginous particles, some of which must be left in the cloth: but the case is worse if the scum is allowed to precipitate upon the cloth. The former is liable to neither of these objections.

THE common fours hasten very fast to corruption; and if, from want of proper care, they ever arrive at that state, must damage the cloth very much. As the milk

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is kept very long, it is often corrupted before it is used ; and, without acting as a sour, has all the bad effects of putrefaction. The vitriol sours are not subject to putrefaction.

THE milk takes five days to perform its task ; but the vitriol sours do it in as many hours ; nay, perhaps, in as many minutes. Their junction with the absorbent particles in the cloth must be immediate, whenever these acid particles enter with the water. An unanswerable proof that the fact is so, arises from the circumstances which happen when the cloth is first steeped in the vitriol sour ; the cloth has no sooner imbibed the acid liquor than it loses all acidity, and becomes immediately vapid. This effect of vitriol sours must be of great advantage in the bleachfield, as the bleachers are at present hindered from enjoying the season by the tediousness of the souring process. The whole round of operations requires seven days ; to answer which they must have seven parcels, which are often mixing together, and causing mistakes. As three days,

Sect. IV. ON BLEACHING. 91

days, at most, will be sufficient for all the operations when vitriol fours are used, there will be no more than three parcels. The cloth will be kept a shorter time in the bleachfield, and so arrive sooner at market.

THE milk fours are very dear, and often difficult to be got; but the vitriol are cheap, may be easily procured, and at any time.

THERE is yet another advantage in the use of vitriol, and that is its power of whitening cloth. It will appear, afterwards, by experiments, that, even in this diluted state, its whitening power is very considerable. We have already seen, that it removes the same colouring particles, which the alkaline lyes do. What of it then remains, after the alkaline and absorbent particles are neutralized in the cloth, must act on these colouring particles, and help to whiten the cloth. That this is really the case, appears from the following fact. Mr *Chrystie* being obliged to chuse twenty of the whitest pieces out of a hundred, five

of the twenty were taken out of seven pieces which were bleached with vitriol.

FROM both experience and reason, I must then give it as my opinion, That it would be for the advantage of our linen manufacture, to use vitriol in place of milk fours.

S E C T. V.

Hand-rubbing with soap and warm water, rubbing-boards, starching, and bluing.

AFTER the cloth comes from the fouring, it should be well washed in the washing-mill, to take off all the acid particles which adhere to its surface. All acids discompose soap, by separating the alkaline salts and oily parts from one another. Were this to happen on the surface of the cloth, the oil would remain; nor would the washing-mill afterwards be able to carry it off.

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FROM the washing-mill the fine cloth is carried to be rubbed by womens hands, with soap and water. As the liquors which are generally employed for souring, are impregnated with oily particles, many of these must lodge in the cloth, and remain, notwithstanding the preceding milling. It is probable, that all the heavy oils are not evaporated by bleaching. Hence it becomes necessary to apply soap and warm water, which unite with, dissolve, and carry them off. It is observed, that if the cloth, when it is pretty white, gets too much soap, the following bleaching is apt to make it yellow: on that account they often wring out the soap. I believe it would be proper to give it always a milling with warm water, before bucking, to take out the soap and loosened dirt more effectually. The preceding fact is a strong argument in its favour.

IT is a matter worth inquiring into, whether hard or soft soap is best for cloth. Most bleachers, I think, agree, that hard soap is apt to leave a yellowness in the cloth.

cloth. I have been told, that the use of hard soap is discharged in *Holland*. As there must be a considerable quantity of sea-salt in this kind, which is not in the soft, and as this salt appears prejudicial to cloth, I would prefer the latter.

THE management of the coarse cloth is very different, in this operation, from the fine. Instead of being rubbed with hands, which would be too expensive, it is laid on a table, run over with soap, and then put betwixt the rubbing-boards, which have ridges and grooves from one side to another, like teeth. These boards have small ledges to keep in the soap and water, which saves the cloth. They are moved by hands, or a water-wheel, which is more equal, and cheaper. The cloth is drawn, by degrees, through the boards, by men who attend; or, which is more equal, and cheaper, the same water-wheel moves two rollers, with ridge and groove, so that the former enters the latter; and, by a gentle motion round their own axis, pull the cloth gradually through the boards.

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Sect. V. ON BLEACHING. 95

THIS mill was invented in *Ireland* about thirty years ago. The *Irish* bleachers use it for their fine, as well as coarse cloth. However necessary it may be for the latter, on account of its low price, I see no reason, on that account, for using it to the former. These rubbing-boards were discharged, some years ago, in *Ireland*, by the Trustees for the manufactures of that country, convinced from long experience of their bad effects. But as proper care was not taken to instruct the bleachers, by degrees, in a safer method, they continued in the old, made a party, and kept possession of the rubbing-boards. There were considerable improvements made in them in this country; such as the addition of the ledges, to keep the cloth moist; and of the rollers, which pull the cloth more gradually than mens hands. These improvements were first made in *Salton* bleachfield.

THE objections against these rubbing-boards, I think, are unanswerable. By rubbing on such an unequal surface, the solid fibrous part of the cloth is wore; by which
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means the cloth is much thinned, and, in a great measure, weakened, before it comes to the market. As a proof of what I say, if the water which comes from the cloth in the rubbing-boards, is examined, it will be found full of cottony fibrous matter. These boards give the cloth a cottony surface, so that it does not keep long clean. Again, they flatten the threads, and take away all that roundness and firmness, which is the distinguishing property of cloth bleached in the *Dutch* method.

FOR these reasons I am of opinion, that they are entirely prejudicial to fine cloth; and hope they will not be employed in this country to it, as I know they still are by many bleachers who follow the *Irish* method. As they seem to be, in some measure, necessary to render the expence of bleaching coarse linen less, they ought never to be used above twice, or thrice at most. They might, I think, be rendered much more safe, by lining their insides with some soft elastic substance, that will not wear the cloth so much as the wooden teeth do.

Sect. V. ON BLEACHING. 97

do. I am told Mr *Chrystie* at *Perth* has lined his boards with short hair, for some years, and finds that it answers very well.

AFTER the coarse linen has undergone a rubbing, it should be immediately milled for an hour, and warm water poured now and then on it to make it lather. This milling has very good effects; for it cleans the cloth of all the dirt and filth which the rubbing-boards have loosened, and which, at the next boiling, would discolour the cloth. Besides, it is observed, that it makes the cloth less cottony, and more firm, than when whitened by rubbing alone.

THE last operation is that of starching and bluing. It often happened, that the cloth, when exposed to the weather to be dried after this operation, got rain; which undid all again, and forced the bleacher to a new expence. To remedy this inconvenience, Mr *John Chrystie*, some years ago, invented the dry-house, where the cloth may be dried, after this operation, in any weather. This invention meets with universal approbation.

P A R T III.

S E C T. I.

Blue pearl ashes.

THE salts or ashes are the principal agents used by the bleacher ; and therefore merit our consideration. A physician who understood not the composition of the medicines he used, would be reckoned ignorant : and why not the bleacher who uses instruments unknown to him ? His ignorance, however, is not blameable. The utmost skill in his art cannot teach him to analyse these ashes into their constituent parts. For that knowledge he must depend on chymistry, which, operating in the gentle method of solution and evaporation, presents to us the natural constituent parts of bodies. The force of strong chymical fire must alter these. A heat as gentle as the summer sun, cannot.

THIS analysis, by discovering to us the constituent

Sect. I. ON BLEACHING. 99

constituent parts of these salts, will teach us the true way of compounding and manufacturing them at home, of procuring them perhaps at a cheaper rate, and not depending on foreign countries for what is absolutely necessary in carrying on our home manufactures. It will be attended with another advantage. As the bleaching ashes of the same name differ very much in strength from one another, this analysis will teach the bleacher how to examine them; how to discover the quantity of salts in them; and, consequently, to ascertain their value and use. It will show him how to discover the qualities of a new salt.

LET us imitate the mathematicians in their method of investigating truth. Let us set out entirely ignorant of the nature, properties, or composition of these different salts; and, by the help of some data, or uncontroverted conclusions from established experiments, proceed to their examination.

THE blue pearl ashes are of a light bluish

ish colour ; have a hot and pungent taste ; and dissolve in the mouth.

Exp. 13. IN order to discover what effect acids would have on these ashes, and what quantity of the former the latter would destroy ; from which I might be able to form some judgment of the quantity and strength of the salt they contained ; I took a drachm of blue pearl ashes, and poured on it a mixture of one part spirit of nitre, and six parts water ; which I shall always afterwards use, and call the *acid mixture*. An effervescence arose, and, before it was finished, 12 teaspoonfuls of the mixture were required. This effervescence with each spoonful of the acid mixture was violent, but did not last long. A reddish powder was precipitated to the bottom. When saturated, it had a nitrous taste.

IT is proper here to give a caution. This experiment does not afford a certain conclusion, either as to the proportion or strength of the real alkaline salts which these ashes contain ; as there are other bodies besides
alkaline

Sect. I. ON BLEACHING. 101

alkaline salts, that effervesce with acids, such as absorbent and calcareous earths, and quick-lime. No certain conclusion can be drawn, unless we were certain, that none of these bodies were mixed with the ashes; which we cannot be, until we have performed the proper trials, fit for discovering the presence of these different bodies.

Exp. 14. To separate the pure saline from the earthy part of these ashes, a half-pound of blue pearl was mixed with three *English* pints of water, and put over the fire. The salt was dissolved when the water was milk-warm. The solution tried several ways, gave me no signs of containing any sulphur. It was strained through brown paper, and left in it a residuum, that weighed, when dried, 3 gr. By another experiment I got a much greater quantity of earthy substance. The strained solution was afterwards boiled into 3 gills, and set in a cellar, that I might discover if there was any nitre, sea salt, or any other kind of salt mixed with the ashes. These salts will discover themselves by their crystallisation.

After

After the liquor had stood a fortnight, there appeared at the bottom of the cup, some crystals that seemed to be much akin to the tartarus vitriolatus. Some of the alkaline salts, and a white powder like the residuum, had mixed with these crystals. This neutral salt will likewise fall to the bottom of the cup, when the solution is near evaporated. The liquor being evaporated, gave me $5\frac{1}{2}$ oz. of salt.

THIS salt was much of the colour of the white pearl ashes; it had lost all its former pellucidity, and was brown on the top, and white beneath. The taste was much the same as before. When half an hour from the fire, it began to turn moist.

Exp. 15. To try the strength of these salts, I dissolved half a drachm in a spoonful of water, and added the acid mixture to it. During the effervescence a whitish powder fell to the bottom. Four tea-spoonfuls of the acid completed the saturation. The liquor being evaporated, gave a nitre.

Sect. I. ON BLEACHING. 103

By this experiment it appears, that the salts extracted by boiling from the ashes, are not so strongly alkaline, as the ashes themselves; and that the boiling, by separating their component parts, which appears by their loss of weight, and precipitation of a powder, weakens them. This ought to teach bleachers not to boil those salts, that are easily dissolved in water without boiling, for by that means they weaken them considerably, but to add them to the lye when cooling.

THE residuum which remained in the brown paper being dried over the fire, tasted and looked like chalk, had no saline pungency, nor was dissolvable in the mouth.

Exp. 16. To three quarters of this I added the acid mixture; a strong effervescence ensued, and a half tea-spoonful was consumed before it ceased.

IT appears from this experiment, that this earth has as strong a power of destroying acids, as the salts themselves. Is this earth,

earth, then, the only absorbent or alkaline part in the composition of alkaline salts? Has their other constituent part or parts, rendered volatile, or changed, by boiling, no opposition to acids? So it would seem. I shall consider this earthy part more fully in the next section.

THE conclusion, then, that we draw from the foregoing experiments, is, That the blue pearl ashes are a very pure alkaline salt, with a small proportion of vitriolated tartar, and absorbent earth.

S E C T. II.

White pearl ashes.

THEY are of a white colour, dissolvable in the mouth, hot, and pungent.

Exp. 17. To a drachm of the white pearl ashes, I added the acid mixture. An effervescence arose, which lasted till the salts

SECT. II. ON BLEACHING. 105

salts had destroyed ten tea-spoonfuls. When saturated, it had a nitrous taste, and a white powder at the bottom. These ashes, then, are a fifth part less antacid than the last.

Exp. 18. To discover the proportion of their earthy part to their saline, half a pound was put into three *English* pints of water; which dissolved when the water began to turn warm; but not just so soon as the blue pearl ashes. The solution gave no sign of containing sulphur. When strained, I got 50 grains of residuum. It was afterwards boiled into three gills, and stood fourteen days in a cellar. I discovered some tartarus vitriolatus, and a good deal of a white powder, like the residuum which had fallen to the bottom. The solution evaporated, gave me of pure salt 5 oz. and 7 dr.

THIS salt was brown above, and white beneath; and, as I thought, had scarce so pungent a taste as before boiling. It began to dissolve in the air, when it had been half an hour from the fire.

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Exp.

Exp. 19. Half a drachm was dissolved in a spoonful of water. They seemed more difficult to be dissolved than the salts of the blue pearl. The solution took four tea-spoonfuls of the acid mixture to saturate it, and let fall a copious white powder, as the salts of the blue pearl had done.

THE residuum is darker-coloured, than that of the blue pearl; but has much the same chalky taste.

Exp. 20. I put six grains of it in a glass, and poured two tea-spoonfuls of water on it. A half tea-spoonful of the acid mixture raised a strong effervescence, and saturated it.

Exp. 21. I put into a reverberatory furnace some of the residuum. After it had been there two hours, it had not the taste of lime, nor afforded me a lime-water. Alkaline salts, each time that they are boiled, and strained, leave a similar earth behind them; and, if the operation be continued, the whole may be converted into
this

Sect. II. ON BLEACHING. 107

this earth. If salts are kept long in fusion, they are turned, at last, into the same earth *. I got some of this earthy matter from pearl ashes, which were strained through brown paper before they were boiled, but could not reduce that earth to quick-lime by the force of a reverberatory furnace. This earth, then, is the fixed basis of alkaline salts; and appears, by these experiments, to be of an absorbent, and not a calcarious nature, as all the chymists, so far as I know, have universally called it. Let us now try to discover the other volatile principle, or principles, that were joined to this earthy base in the composition of alkaline salts.

THERE are two different opinions with regard to the formation or origin of these alkaline salts. The former is, That they pre-exist in vegetables in the same form, and are separated from the other parts, by incineration †. This opinion is

* Junker de salib. alkal. fix. p. 372.

† Burning to white ashes.

now universally exploded, as no such salt has ever, without the assistance of fire, been discovered in plants, though it is found elsewhere. The other opinion is, That they are produced, by the act of combustion, from some new combination of the parts of the plant, that were not combined before. This is the opinion of *Stahl*, *Boerhaave*, *Junker*, and almost all the chymists. They seem not to be agreed, however, as to the principles that go to their composition. *Stahl* imagines they arise from a junction of the heavy inflammable part with the saline. From the known experiments of making alkaline salt from nitre and any inflammable body, he draws this conclusion. *Item, itaque hoc in vegetabilium incineratione contingere, et ita alkalia illorum nihil aliud esse quam partem illorum nitrosam, cum bituminosa deflagrando commixtam, sequentia phænomena confirmant**. *Junker* differs from *Stahl*, in associating the inflammable, acid, and terrene parts toge-

* Art. 3. de sal. volat. plantar. fund. chym. A book published by one of his scholars; and though not by himself, yet with his connivance.

ther :

ther : *Sub ingenti autem illarum commotione, pars acida ex mixtione sua ibidem resolvitur, et terrenis partibus illiditur; cum quibus, si cum fixiore sulphurea firmiter complicatur, generat et constituit substantiam illam alkalinam fixam* *. The arguments produced by them in proof of an inflammable principle, do not seem, to me, to be sufficient. The argument that *Stabl* brings in defence of his opinion, is this. If a plant, which affords plenty of alkaline salt, be dried, bruised, and digested in spirit of wine, until all the resinous part be extracted, then burnt in a gentle fire, (*leni igne*), it will afford a nitrous salt, but not an alkaline one; because, says *Stabl*, the resinous part, that should go to its composition, is carried off. This conclusion of *Stabl* seems to me too strong. It proves that an inflammable principle is necessary to the production of an alkaline salt, but it proves no more. To say that it is necessary in the composition, is saying more than the experiment will allow. The inflam-

* De salibus alkalinis fixis, tab. 66.

mable principle is absolutely necessary in the production of alkaline salts, in order to make a great commotion and heat in the vegetable, by which alone the acid parts are to be driven off. A gentle external fire, after the oil, which is the support of the internal fire, is withdrawn, can never be sufficient for this purpose. Chymists have observed, that a smothered fire produces little or no alkaline salt. This shows a flame to be absolutely necessary.

THIS reasoning serves, likewise, as an answer to the experiment mentioned before, by which an alkaline salt is produced from nitre and an inflammable body. *Junker* has another argument in support of an inflammable principle. "If," says he, "an alkaline salt saturated with distilled vinegar is again exposed to the fire, it gains a black colour; which is an undoubted proof, that it contains a heavy inflammable substance." Undoubted I'll allow it to be; but whence comes it? From the distilled vinegar, to be sure, which contains a heavy oil in considerable quantity.

THESE

Sect. II. ON BLEACHING. 111

THESE experiments, therefore, are not sufficient to prove the existence of an inflammable principle in alkaline salts. But the experiments that prove the contrary, are very strong. Whatever body contains an inflammable principle, deflagrates with nitre in fusion ; but alkaline salts do not. Whenever alkaline salts and an inflammable body are joined, they emit, when the mineral acids are poured over them, a sulphureous smell ; but alkaline salts do not. When an oleaginous substance is joined to alkaline salts, a substance different from either, called *soap*, is formed. The chymists themselves acknowledge, that alkaline salts may be formed of two bodies, neither of which contain an inflammable oleaginous principle. These quotations from *Stahl*, show how much he differs from himself. Fund. chym. part. 2. p. 50. *Calx viva, vel cum vitriolo, vel sale communi, aut spiritu acido, mixta, et calcinata, præbet sal fixum acerrimum, solubile.* p. 52. *Sic spiritus acidus salis cum creta mixtus, mutatur in sal alkali fixum.* Ibid. p. 54. *Nempe spiritus acidus salis commixtus cum creta, coral. ust. calce viva, trans-*
mutatur

mutatur in sal alkali, quod eosdem effectus præbet in solutionibus et præcipitationibus cum sale quodam fixo alkalino. These experiments, if he has performed them, shew plainly, that an inflammable principle is not necessary. But I must own, that these experiments, though they make against the theory I have been endeavouring to refute, did not succeed with me, as they have done with *Stabl.*

I shall relate what success I have had in these experiments. In the first quotation he orders the neutral body, made of quicklime and the spirit of salt, to be calcined; and though he does not mention calcination in the two last, it must be understood; for otherwise the bodies saturated would be neutral, and not alkaline.

Exp. 22. Two scruples of chalk being fully saturated with spirit of sea salt, gave a yellow, bitter, pungent liquor. This, when dried, and put immediately into a gentle fire for some minutes, gave no signs of effervescing with acids, but attracted the moisture

Sect. II. ON BLEACHING. 113

sture strongly. It was again put into a crucible, and set in the middle of a kitchen-fire, for two hours. Still it raised no effervescence with acids; but had some of the other properties of alkaline salts, such as turning moist in the air, dissolving in water, and turning syrup of violets green. It was afterwards put into a reverberatory furnace for an hour and a half; but by this heat it seemed to have been turned into glass; for there was nothing to be found in the crucible, and its bottom had a glazed-like appearance. Thus a calcarious earth, invitrifiable before, is turned, by the addition of an acid, into glass.

Exp. 23. Two scruples of quick-lime were saturated with spirit of sea salt, which produced a yellow caustic liquor, that burnt the tongue when applied to it. Being evaporated, and kept in the kitchen-fire for two hours, I got a substance that scarcely dissolved in water, nor in the least effervesced with acids; but turned syrup of violets green, and tasted just like alkaline salts. It was put for an hour and a half in a reverberatory

ratory furnace, and I had 22 gr. of a gritty undissolvable substance. Thus the acid has changed the calcarious base into an earthy substance, that is of a different nature from quick-lime.

I pursued these trials further, to see if I could succeed better with the other mineral acids.

Exp. 24. Chalk was saturated with spirit of nitre, and then put into a kitchen-fire for half an hour. I got a substance which was undissolvable in water, and to me appeared to be like chalk.

Exp. 25. Quick-lime saturated with the spirit of vitriol, afforded a bitter caustic liquor, which excoriated my tongue. When evaporated, it was put into the kitchen-fire for an hour. I got a brown substance, which was a little hot in the mouth, did not appear to be dissolvable in water, and afforded a lime-water.

FROM these experiments it appears, that

Sect. II. ON BLEACHING. 115

a substance formed of an acid salt and absorbent earth, has some of the properties of alkaline salts, while it wants others. The chymists, for they generally follow *Stahl* in this opinion, have been led astray by the caustic taste of the production. Notwithstanding the ill success of these experiments, to prove, that alkaline salts are a compound of an absorbent earth and an acid, yet I still think there is a great degree of probability in that side of the question, from the following reasons.

THOSE plants which contain no acid, afford no alkaline fixed salt, such as onions, mustard, &c. If such plants as contain an acid, are distilled, and the acid forced over with a strong fire, they afford less alkaline salt. Alkaline salts are made more alkaline by a stronger heat than what was used before; which shows, that more of the acid has been driven off by the fire. "Nitre, without any addition, kept long in fusion, acquires a caustic alkaline nature*." There are scarce any of the properties of

* Junker de salib. alkal. fix.

alkaline salts, but what belong either to the absorbent earths, or acids. To the former they owe their fixedness in the fire, their attraction and effervescence with acids, with all the properties that depend on this cause, and their power of turning the syrup of violets green: to the latter, their caustic power, their solubility in water, their transparency when dissolved in it, their attraction of moisture, their junction with oils, and their vitrescency. If there are any particles of fire added to, and fixed in the alkaline salts, as it is probable there may be, these may a little vary some of the properties: As for instance, alkaline salts attract acids with a greater force, than absorbent earths do, though the last destroy a greater quantity. This stronger attraction in alkaline salts may be owing to their parts being more opened, than those of the earth, to the junction of some particles of fire, or, perhaps, to the remaining acid particles, between whom and the other acid there may be an attraction. This doctrine will receive an additional strength, by considering, out of what substance or substances, pre-existing
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in the plant, those alkaline salts are formed.

THE general opinion of chymists, as I mentioned before, is, that they are formed by a new combination of principles during combustion. I imagine they are formed by a separation. The essential salts of plants seem to be the product of an acid, and an absorbent earth; for these two, as we have showed before, are sufficient to make a neutral salt. There is no fact, I think, more clearly proved, than that there are acid particles continually circulating, in greater or less quantity, with the air. I have tried the ashes of plants, and I find they contain a great quantity of absorbent particles. Hence, then, the essential salts of vegetables. But these salts extracted, crystallised, and calcined by themselves, afford, as *Boerhaave* informs us, an alkaline salt. Why not likewise when the vegetable is burnt? This is the most natural way of accounting for their origin, without flying to new combinations during combustion. The fire will evaporate all the water, dispel the greatest part of the acid from these neutral

tral salts; and there will remain a small quantity of pure solid acid, joined to an absorbent earth *, with, perhaps, some particles of fire in the composition.

S E C T. III.

Muscovy or blanch ashes.

THE bulk of mankind are led by names. That two substances enjoy the same denomination, is enough, to the

* Long after these papers were wrote, I discovered the same opinion, with regard to the composition of alkaline salts, in the writings of a celebrated chymist, *Homborg des principes de chymie en general.*—*Memoires pour l'annee 1702.*

Ces sels fixes lixiviels ne sont autre chose qu'un reste des sels acides, que le feu de la calcination n'a pu separer de la terre du mixte, qui lui sert de base, et qui se dissolvent ensemble dans l'eau commune.

The following quotation from the same dissertation, appears to be an experimental proof of this doctrine. *La seconde occasion ou ces sels fixes peuvent devenir volatils, est de les dessoudre dans de l'eau, le tenir pendant quelque temps en digestion, ensuite de les filtrer et evaporer, puis recommencer ces operations plusieurs fois, jusque à ce qu'à la fin ces sels se cristallisent: alors il le faut meler avec du bol, et les destiller à grand feu, il en viendra une esprit acide: les sels fixes retires de la tete-morte traite de la même maniere en rendra encore un peu, mais en très petite quantité.*

careless

Sect. III. ON BLEACHING. 119

careless observer, to rank them in the same class, and to imagine their composition and qualities, in general, much alike: else how would the *Muscovy* ashes have ever been classed with those above explained, when the external senses, without further help, might, if attended to, have discovered the fallacy, and shown these to be of a very different nature from the two former?

MUSCOVY ashes have very much the appearance of slaked lime; and are, like it, friable betwixt the fingers. The tongue, when applied, adheres to them. The first taste which one perceives, is that of an alkaline salt; but this goes soon away, and leaves a strong taste of lime, which is peculiar to this salt. They never turn moist in the air; which plainly discovers, that they contain little alkaline salt. Some small bits of charcoal are to be seen in their composition.

Exp. 27. On the addition of the acid mixture to a drachm of *Muscovy* ashes, there arose an ebullition, which, though it was
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not violent, yet continued long after the acid was joined to it. When they had got 4 spoonfuls, I took out a little piece to break it; and to the taste it seemed insipid, and gritty like a stone. They consumed 17 tea-spoonfuls. When the saturation was fully completed, it tasted bitter, and very different from the two former salts.

Exp. 28. To separate the salts from these ashes, I put half a pound in two pounds of water, and kept it pretty warm over the fire, but did not let it boil, for fear of dissipating the volatile parts, if there were any, till I thought the salts would be dissolved; then I poured off the water. A half-pint was added to the remaining powder, which, after boiling some minutes, was likewise poured off. It was treated twice more in the same way. The last that came off was not salt, but had a taste like lime-water. The decoction all together, when strained, was about three pints. Though carefully examined, it gave no sign of containing sulphur. After all was strained, there remained in the paper $5\frac{1}{2}$ dr. of a whitish powder,

SECT. III. ON BLEACHING. 121

der, which added to 2 oz. 5 dr. of undissolvable substance, that lay at the bottom of the pot, when the water was poured off, made in all 3 oz. 5½ dr. This decoction boiled into half a pint, and set for a fortnight in a cellar, gave no sign of any other salt. When all the water was evaporated, I had 10 dr. 15 gr. of a very caustic salt, which seemed lighter than the salts of the blue and pearl ashes, and turned very moist, when kept from the fire twenty-four hours.

It appears that 3 oz. 18. gr. have been rendered volatile by the water, a greater quantity than in any of the two former salts. This loss of substance probably arises from the watery parts contained in these ashes.

Exp. 29. To ascertain the strength of these salts, I dissolved half a drachm in water. The acid mixture produced a stronger effervescence than with the former salts; and four and a half tea-spoonfuls of it were required to saturate it. A

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brownish

brownish powder fell to the bottom of the glass in great quantity. These salts, then, appear to be stronger antacids than the former two, by their greater ebullition, and the greater quantity of acid they consumed. If we are to judge by the last article, their proportionate antacid strength (for this experiment may be no rule as to their other qualities) is as nine to eight. It appears likewise, that the antacid quality of the ashes themselves is almost double to that of the salts. Can this be owing to the volatility of some acid parts? or to the greater antacid power of the other part that is mixed with these salts? This last appears probable from the following experiments, which discover a stronger antacid power in the residuum than in the salts.

LET us now examine the residuum, which, as I mentioned before, was of two sorts; what remained in the bottom of the pot, and what remained in the gray paper. The first was of a light brown colour, and run together into hard pieces; the latter was white, and a powder.

Exp.

SECT. III. ON BLEACHING. 123

Exp. 30. Thirty grains of the latter effervesced strongly with the acid mixture, and consumed five and a half tea-spoonfuls. Thus, though the residuum appears stronger than the salts, yet it seems much weaker in its antacid power than the ashes.

I poured water on a quantity of both residuums in two different cups, and let it stand all night. The water had a taste of chalk and water, next morning, but not of lime-water.

THIS substance might still be calcarious, though it had no parts now soluble in water; for the reiterated boiling in water might have carried off these soluble parts, as we know it does. My next trial, therefore, was, to see if I could reduce it to quick-lime again, by the force of the fire. There is no doubt but that the fire will reduce into quick-lime, at a second trial, those calcarious parts, which had not got a sufficient fire the first time, and on that account were not calcined into quick-lime. We often see undissolved in the water pieces

of lime-stone, which would have been reduced to quick-lime had they got sufficient fire. But whether those parts of quick-lime, which have been sufficiently calcined, and have been robbed of all those particles that are soluble in water, can again be reduced to quick-lime, is not, I think, clearly ascertained by authors who have wrote on this subject.

Exp. 31. To determine this question, I tried the following experiment. A considerable quantity of quick-lime was quenched in water, so that it rose some inches above the lime. The whole was often stirred about. After it was completely settled, I took of the surface of the lime, which was composed of those particles that had been the longest suspended in water, and of course the finest. This lime, that could have no particles in it but what had been separated by the water, and therefore none but those that had been changed into quick-lime by the fire, was boiled in water until it no longer tasted like lime-water. This took two days boiling. The
effete

Sect. III. ON BLEACHING. 125

effete lime was then put into a reverberatory furnace, for an hour and a half. This reduced it again to strong quick-lime; for it sucked up the water very greedily, fell down into powder, and afforded a strong lime-water with a pellicle.

Exp. 32. Some of the residuum of the white *Muscovy* ashes, put in a strong kitchen-fire for two afternoons, and afterwards mixed with water, did not fall; after it had stood some time, the water had no pellicle, nor a taste of lime-water, but as if chalk and water had been mixed together.

BUT the same substance, kept in a reverberatory furnace for an hour and a half, gave me a strong lime-water with a pellicle. The residuum then appears to be the *caput mortuum* of quick-lime.

Exp. 33. Another experiment of the same kind I tried at the bleachfield. I took some of the *caput mortuum*, which remains in the copper after the lye is taken off, and will

will not dissolve in water. It had no taste but that of an earth. It was calcined in a large strong fire for two hours; when cold, water was poured on it, which made an ebullition, and caused it to fall down. When the liquor had stood all night, it had the pellicle and taste, though not very strong, of lime-water.

LET us see if we cannot make a lime-water from the *Muscovy* ashes, without the assistance of fire.

Exp. 34. Two ounces of them were washed, by continual addition of fresh water, till the water that came off from them had no longer a salt taste. Then I poured some water over them, and let the mixture stand all night. Next morning it had the pellicle of lime-water; and appeared, on tasting, to be good lime-water.

As a further proof, we could have distilled some of the ashes, after the salts had been washed out, with crude ammoniac salt, and seen whether the volatile spirit was like that

Sect. IV. ON BLEACHING. 127

that produced from lime and that salt; for a spirit produced in this way, is found to differ very much from a spirit produced by an alkaline salt in place of lime. But my ingenious friend Dr *Cullen* has prevented me; and, having distilled *Muscovy* ashes and sal ammoniac together, got such a spirit as is procured from the latter and quick-lime. By this experiment he made it highly probable, that lime entered into the composition of the *Muscovy* ashes; and is, therefore, justly intitled to the merit of being the first discoverer.

FROM these experiments the following corollary follows, That the *Muscovy* ashes contain an alkaline salt and lime; and the latter in much greater proportion than the former.

S E C T. IV.

Cashub ashes.

THESE ashes are extremely hard, of the colour of iron stone, with many shining

shining particles, and some pieces of charcoal in them. They have a saline taste, with a considerable degree of pungency. They feel gritty in the mouth, when broke in pieces by the teeth; for they will not dissolve.

Exp. 35. When the saline mixture was poured over them, they did not effervesce violently, but long; and the liquor had a very black powder on the top and bottom. They emitted a sulphureous smell; and, when the saturation was completed, which was done by 13 tea-spoonfuls of the acid mixture, they had a sulphureous taste.

Exp. 36. To extract the salts, a half-pound was boiled in a pint of water; then that water poured off, and a half-pint put on the ashes again; and so on till the water tasted no longer salt. This boiling took twenty-four hours. The last that came off had a strong taste of sulphur, and was blackish.

Exp. 37. To try if there was any sulphur in the decoction, I put a piece of silver in-

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SECT. IV. ON BLEACHING. 129

to it; which in a few minutes was turned almost quite black.

Exp. 38. This experiment corroborates the former. Into 1 oz. of the decoction I poured as much spirit of nitre as saturated it. During the addition of the spirit there was a strong smell of a volatile sulphur. The liquor turned lactescent, and let fall to the bottom a light-coloured powder in considerable quantity. I strained the whole through brown paper; and there was left in it a sulphureous smelling substance, which, when dried, weighed one fourth of a grain. This substance, when burnt on a red-hot iron, had not a blue, but pale-red flame, and a very gentle smell of burnt sulphur. As this is a vegetable sulphur, that is to say, an inflammable body joined to a vegetable, and not a mineral acid; it probably differs from the mineral sulphur in the strength of its qualities, and, therefore, may not have such a strong smell as the latter.

LET us try if we can ascertain the quantity of this sulphureous matter in the decoc-

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tion.

tion. It is very volatile, and therefore cannot be caught, so that we might weigh it. Let us take its power in colouring silver, and see what light it will afford us in this intricate scrutiny. The less the quantity of sulphur, the weaker the colour. I took .3 gr. of sulphur, opened by an alkaline salt, and diluted it so with water, that the solution had lost all taste, and took two hours to alter the colour of silver in a small degree. The quantity of water used was five pints. When two pints more were added, it lost altogether this quality. To apply this experiment to the present question,

Exp. 39. I diluted a small quantity of the decoction, so that it took the same time to have the same effect, as in the former trial. The proportion of water to the decoction was, as 192 to 1. There was three pints of the whole; therefore 192 multiplied by 3, gives the quantity that could be made out of the whole decoction of this weak sulphurated mixture, which is 576 pints. So that dividing the number
of

Sect. IV. ON BLEACHING. 131

of pints by 5, and then multiplying them by 3, we have the number of grains of sulphur in this decoction. The whole then is 5 dr. 35 gr. and about a half, in the decoction, besides what remains in the residuum, which seems to be more. Every bleacher, if he extracts all the salts from the *Cashub* ashes, must have that quantity of sulphur from each half-pound of the ashes; and if he boils them longer, he will probably have more. The only objection to this reasoning is, That we have argued from a mineral sulphur to a vegetable one, and supposed their powers of tinging silver to be the same. As I cannot positively assert them to be the same, I must allow this objection to have some weight; though it is probable there may be little difference betwixt them in this quality.

WHEN the decoction was boiled into a gill and a half, it did not turn silver black more speedily than before boiling; which shows the sulphur to be as volatile as the water. This quantity stood for some days in a cellar, but no sign of any crystallisation.

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It was boiled into a gill, and set by again. After standing twelve days, I looked to it, and found it gellied. This was evaporated, and gave me 10 dr. of a brown salt, that had a strong alkaline caustic taste. By another experiment, in which the salts were separated by cold water, I got a small quantity of a neutral salt, like the vitriolated tartar, from these ashes.

Exp. 40. The alkaline salt, tried with the acid mixture, effervesced, and consumed four and a half tea-spoonfuls of it. Thus we find the antacid power of the salt is much weaker, than that of the ashes.

I had two residuums, one left in the pot, and another in the brown paper, of a blackish colour; both which weighed 5 oz. 7 dr. The loss in boiling, then, amounts to 7 dr.

Exp. 41. On 1 dr. of the residuum powdered I poured the acid mixture. An effervescence arose; the whole turned very black, sent up a strong sulphureous smell, and

Sect. IV. ON BLEACHING. 133

and tinged the piece of silver black. Twenty tea-spoonfuls of the acid were consumed. After the saturation there was some of the earthy part of the residuum at bottom ; above it lay a black stuff like tar ; then the liquor, which was now pellucid, though it was not so all the time of effervescence. A black scum remained on the top till next morning, which then fell to the bottom on stirring. What remained in the paper, when the liquor was strained, weighed half a drachm. The liquor being almost evaporated, was set to crystallize.

AFTER standing some time it was gelied. Being evaporated over a slow fire, it gave me 44 gr. of a pale-red saline substance, but no crystals. This saline substance attracted the moisture so strongly, that it could hardly be dried, unless put in a strong heat ; and, when taken from the fire, turned immediately wet again. It seemed to agree pretty much with the saline substance that I spoke of before, composed of lime and spirit of nitre.

Exp.

Exp. 42. Some *Cashub* ashes powdered, and often washed with water, so that the salts were all carried off, were infused in water. After standing some time, I had a weak lime-water, that had still somewhat of a saline taste, and had no pellicle.

Exp. 43. Some of the residuum was put into a reverberatory furnace for two hours. After that it afforded me a good lime-water. *Cashub* ashes, then, appear to contain an earth half vitrified, some lime, alkaline salts, and a sulphureous, inflammable, volatile substance.

LET us inquire whence arises the sulphur of these ashes, of what sort it is, and what are its effects. Sulphur is a composition of the acid of vitriol, and an oil. Any kind of oil will serve, whether vegetable or mineral, and make no difference in the composition; but no acid will do except that of vitriol. The acid of most trees seems to be of the vitriolic kind. When they are burnt, the fire dispels all the watery parts, with some of the acid, and the

SECT. IV. ON BLEACHING. 135

the more volatile oils ; while the remaining acid, more concentrated by loosing the watery particles, unites with the heavy oils, and so forms a sulphur ; which remains in the ashes, if the fire is not sufficiently strong, or not continued long enough to consume it ; for all charcoal, if fused with alkaline salts, discovers a sulphur. It is remarkable, that charcoal does not tinge silver when rubbed on it, nor shows any other of the effects of sulphur, until it has been opened by an alkaline salt. All these materials are found in the *Cashub* ashes ; and therefore no wonder that they contain a sulphur.

BUT does this vegetable appear to be the same with the common mineral sulphur ?

HOMBERG has given us a division of sulphurs into the vegetable, the animal, the bituminous, and the mineral ; and has misled many by it. That *Homberg* means the inflammable principle by the word *sulphur*, appears from these words. *L'huile de la plant,*

plant, qui est leur matiere sulfureuse *.—He was to blame, as well as most of the chymists have been, for the vague use of that word. That division, therefore, cannot affect the present question.

It is plain that common sulphur may be made as well with a vegetable as with a fossil oil. The acid of vegetables seems to be of the same nature as that of vitriol; for with the acid of some vegetables and the salt of tartar, a tartarus vitriolatus arises; and with iron or copper, a vitriol of these metals. The acid of many plants seems to differ from that of vitriol, only because the former is weaker than the latter. It would appear, therefore, that vegetable sulphur would nowise differ from mineral but in being weaker.

THE effect of this substance upon cloth is to discolour it; as every bleacher knows, if he uses a lye of kelp ashes, or any other sort of ashes much impregnated with sul-

* *Mem. de l' acad. des scienc. 1702.*

Sect. IV. ON BLEACHING. 137

phur, when the cloth has attained a considerable degree of whiteness. Let none, however, imagine, that this sulphureous substance tinges linen, as much as it does silver. This is an effect peculiar to that metal. Sulphur, when mixed with alkaline salts, is soluble in water, and may in that state be taken out of the cloth by mill-washing. But if the alkaline salts are separated from the sulphur, by their stronger tendency to solution, by their transmutation into an absorbent earth, by meeting with an acid in the water thrown on them, or in the operation of souring, the sulphureous matter, freed from its alkaline dissolvent, will be precipitated on the surface of the cloth; nor will water have the least effect in removing it. A pure lye would again dissolve this sulphur; but the continuation of an impure one must increase its quantity. Hence the necessity of a greater evaporation, and longer exposition to the sun and winds; the only method left, during the use of a foul lye, to carry off these colouring sulphureous particles.

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S E C T. V.

Marcoft ashes.

THE *Marcoft* ashes are of a paler colour than the former, and have some small pieces of charcoal in their composition. They have a strong saline taste, with so great pungency, that they cannot be held long in the mouth.

Exp. 44. The acid mixture kept up a long fermentation, but not a violent one. A dark-coloured substance rose to the surface, and likewise lay at the bottom on the surface of the ashes. A strong sulphureous smell arose; and after saturation, which was performed by 13 tea-spoonfuls, the liquor had a sulphureous taste.

Exp. 45. Half a pound was boiled as the former, and during the same time. The decoction was not so black as the *Cashub*, and had not the sulphureous smell. I forgot to try it when turbid; but the strained decoction,

Sect. V. ON BLEACHING. 139

decoction, having some of the residuum left in the paper mixed with it, had no effect on silver.

ONE ounce, therefore, of *Marcoft* ashes was boiled in a pint of water to half the quantity. This decoction coloured silver very suddenly; and when saturated with spirit of nitre, let fall a great deal of sediment. When diluted with 96 waters, it just tintured silver. So that the *Marcoft* seems to contain about the half of the sulphur that the *Cashub* ashes do.

THE former decoction boiled into two gills, did not tincture silver. It appears by these experiments, that the sulphur in this salt is much more volatile than the former, and that the whole of it, by continued boiling, may be dissipated. On this account it seems fitter for bleaching. The decoction having stood some days, and giving no sign of any other salt, was boiled into a gill. This set by for twelve days, turned into a gelly. When entirely evaporated, I had of a saline substance 11 dr. 1 scrup. and 2 gr.

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which

which added to $5\frac{1}{2}$ oz. of residuum, showed the loss to be 1 oz. 38 gr. By another experiment, in which the salts were separated by an infusion of cold water, I got a small quantity of a neutral salt, like the *tartarus vitriolatus*.

Exp. 46. This salt procured by the former experiment, tastes strongly alkaline; and a half-drachm took 4 tea-spoonfuls of the saline mixture to saturate it. During the effervescence I thought I felt a sulphureous smell.

THE residuum was much of the same colour with the ashes; and is quite insipid and undissolvable in the mouth.

Exp. 47. On 1 dr. of it I poured the acid mixture, which raised an effervescence much greater than the residuum of the *Cassia*; but did not turn black, nor send up a sulphureous smell, nor tinge silver. It consumed 26 spoonfuls. After saturation, there was a black tar-like substance resting on the remaining powder. The liquor, being

Sect. V. ON BLEACHING. 141

ing strained, left 7 gr. of residuum. When evaporated, I had 1 dr. 9 gr. of a saline substance, that would not crystallize, had a greenish yellow colour, and attracted the moisture strongly from the air. The antacid quality, therefore, of the earthy part, is to the same quality of the saline part, as $3\frac{1}{4}$ to 1.

Exp. 48. To discover whether the residuum was a calcarious earth, a half-ounce was put for an hour and a half in a reverberatory furnace, during which time it lost 1 dr. and 1 scrup. When put into water, it did not hiss when mixed; yet next morning I had a strong lime-water, with a pellicle from it.

Exp. 49. To try if I could discover any lime in the ashes themselves, without the assistance of fire, I washed the salts well out with water, after which they afforded me a weak lime-water.

THIS salt, therefore, seems to contain the same principles with the former; only the

the sulphur is in less quantity, and more volatile.

It is proper here to inquire, whether alkaline salts produced from different bodies, differ from one another? In examining this fact, chymists generally state the question thus: "Have alkaline salts any specific difference?" Almost all of them determine in the negative." *Stahl* says, *Fund. Chym.* p. 85. *Nitrum itaque plantarum, cum generali illa oleositate crassa seu resina, conflagrando, in omnibus vegetabilibus, quæ alkali fundunt, unius generis alkali constituit.* They allow, that one salt is more caustic than another, that one is more pure than another; but this, say they, is owing to the accidental management of the fire, or the accidental mixture of other bodies. They all allow, that salts extracted with tepid water, are not so impure, as those with boiling water. The quicker or slower evaporation is observed to make a difference. But these causes are still accidental. The *soda Hispanica* is observed to make finer glass, than the much purer salt of tartar. But this is owing to a mixture

ture of sea salt with the *Spanish* kelp ashes, and a mixture of inflammable matter with the salt of tartar. Many other differences are observed betwixt the different alkaline salts; but these, they say, are owing to accidental, and not to specific qualities.

LET us understand the terms of the question aright, before we argue on it. The question is thus stated by *Stahl*. *An ut plantæ, ita etiam earum salia fixa, specie et specifico effectu differunt* *? If he means to inquire, whether these salts have the specific qualities of the plants from which they are got? the question will soon be determined in the negative. For the salt of poppy enjoys no narcotic quality, nor the salt of ipecacuahn an emetic, nor the salt of jallap a purgative, nor the salt of hemlock a poisonous. But if he means that one kind of alkaline salts have no specific qualities, whereby they differ from another kind, and which the latter, treated the same way, may not acquire; and this, by

* Fundam. Chym. p. 85.

the quotation preceding the last, seems to be his opinion; I must, determined by a variety of experiments made by others, dissent from such a great chymist, and assert, that "alkaline salts have a specific difference." Experiment alone can determine this point, and to experiment I shall refer the decision.

THE alkaline base of sea salt is found to enjoy some particular properties, which no other alkaline salt has. It crystallises like the neutral salts. It does not turn moist in the air; but, on the contrary, loses that water which crystallised along with it, and, of course, its transparency. When it is combined, and saturated with the vitriolic acid, it forms Glauber's salt; a salt differing in the figure of its crystals, its easy solution in water, and fusion in the fire, from vitriolated tartar, or a salt made of the same spirit of vitriol and the salt of tartar. When it is saturated with the spirit of nitre, there arises a neutral salt, differing from nitre, as it powerfully attracts humidity; and its crystals are of a quadrangular figure.

HOFFMAN

HOFFMAN, in his 29th observation, has shown us how differently experiments succeed with different alkaline salts. The alkaline salt of nitre prepared with charcoal, exhaled the smell of *aqua fortis* on an effusion of spirit of vitriol; which salt of tartar, or potashes, do not; owing perhaps to some of the spirit of nitre that is not dispelled by the deflagration. If powder of charcoal is added to salt of tartar, or potashes in fusion, a sort of *hepar sulphuris* is formed; but this does not succeed with the alkaline salts made of nitre and charcoal, or nitre and the regulus of antimony. Salt of tartar, made with or without nitre, differs from the lixivial salts; for, on an effusion of oil of vitriol, a fetid smell arises, a black scum gathers on the top, and the whole mixture at last gains the same colour. The salt made of two parts nitre and one of the regulus of antimony, affords a red tincture with spirit of wine; which a salt formed of two parts of nitre and one of tartar, or the common potashes, do not. These specific differences in the salts of the two last experiments, seem to be owing to some of the

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oily or sulphureous particles, which still lurk in them, notwithstanding all the fire they have sustained.

It appears, then, from these experiments, that alkaline salts prepared in the common way, from different substances, are specifically different; and probably have different effects when taken into the human body; but these effects are so gentle, and so mastered by the alkaline property common to all, that they pass unobserved. The fire at length seems to dissipate these specific properties, and to reduce the different alkaline salts, freed from heterogeneous particles, to one similar nature. The purer these salts are, so much the fitter are they for the uses of bleaching. The effects of the sulphur in the *Cashub* and *Marcoft* ashes, have already been explained. The great quantity of sea salt which is in kelp ashes, may render them unfit for bleaching. But this still stands in need of further proof. I do not think that any other small differences betwixt these alkaline salts can affect their operation on cloth; be-
cause

Sect. VI. ON BLEACHING. 147

cause that depends entirely on their alkaline property, which can only differ in degree.

S E C T. VI.

Method of manufacturing these ashes at home.

ALL reasoning and experiment ought to be connected with the affairs of mankind; and the closer this connection is, the more valuable these efforts of the human mind become. It is by this consideration alone their value ought, and will be measured. But what can touch us more nearly than the improvement of our manufactures, on which the riches of our country, and the daily bread of the greatest number of its inhabitants depend? With this view, then, I shall endeavour to make the foregoing experiments more useful, and adapt them to the advancement of bleaching, by discovering how we may make these ashes, at a much cheaper rate, amongst ourselves, while we employ our

own hands, and thereby save the nation much money. By showing how these ashes may be compounded, we shall be able to give the preceding conclusions their full conviction.

THE blue and white pearl ashes we have discovered to be pure alkaline salts, without any considerable mixture of heterogeneous bodies. Their purity shows the lixive to have been strained through some close substance, such as linen, or flannel. The blue ashes shew, by their colour, that they have sustained the most fire. But both of them are so much alike, that the one may be substituted for the other; and therefore we shall consider them in one view.

EVERY one knows, that alkaline salts, such as these, are got from all plants except the alkalescent, and from all trees except the most resinous, which afford them in very small quantity. These plants, or trees, when found, are pulled or felled in the spring, dried, and burnt to ashes. By the effusion of warm water the salts are dissolved,

solved, and, by straining, separated from the earth along with the water. This saline liquor, which is called a lixive, is evaporated over a fire; and what remains, is an alkaline salt of the same kind with the pearl ashes.

I was informed by a skilful bleacher in *Ireland*, that he practised a more expeditious way of extracting the salts. He bought the ashes of different vegetables from the commonalty for 9 s. a-bushel. From these a very strong lye was made, into which dry straw was dipped, until it sucked up all the lye. This straw was afterwards dried and burnt, and gave him salts which he showed me, almost as good and pure as the pearl ashes. This method I have several times tried; but could never burn the straw to white ashes, the salts diminishing the inflammability of the straw. It is a very expeditious method, if it can be practised. But I can see no occasion for bringing the lye into a solid form, as the salts must again be dissolved in water before they can be used.

used. The strength of the lye can easily be determined by the hydrostatical balance.

THOUGH I make no question, that the quantity of salt, in plants of the same species, will vary in different soils and climates; yet it would be of advantage to have the proportion ascertained in general. Some trials of this kind I have made.

Exp. 50. Two pounds of fern which had been pulled *August* 16. were dried, and burnt to white ashes. These weighed 7 dr. and tasted very salt. When lixiviated, strained, and evaporated, they gave me 49 gr. of salt, about the eighth part of the ashes. If the fern had been pulled in *April*, it would have afforded more salt. Why then should we not prepare salts from this vegetable? There is more of it growing on our hills, than would serve all our bleachfields. The *Irish* make great use of it.

Exp. 51. From 11 oz. of tobacco ashes I had 1 oz. of salt. Two oz. of peat ashes afforded half a drachm of salt. Nettles, I

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Sect. VI. ON BLEACHING. 151

am informed, afford much falt. Furz and broom, natives of this country, are very fit for this purpose.

BUT the kelp, as it grows in such plenty along our shore, and contains more salts than any other vegetable I know, would be the most proper, were it not for a mixture of some substance that renders it unfit for bleaching, at least of fine cloths, after they have attained a tolerable degree of whiteness. It is observed by bleachers, that, in these circumstances, it leaves a great yellowness in the linen. As these ashes are much used in *Ireland*, and as it is not uncommon to bleach coarse cloths with them in *Scotland*, a disquisition into their nature, and some attempts to purify them, may not be improper. There are no ashes sold so cheap as these; for the best gives but 2 *l.* the 2000 weight. They may, therefore, allow of more labour to be expended on them, and come cheaper at long-run than the foreign salts.

Exp. 52. I dried some sea-ware, and burnt it,

it, though I found that last operation very difficult. When I had kept them fused in the fire for two hours, they weighed $3\frac{1}{2}$ oz. I poured on the ashes an *English* pint and a half of cold water, that I might have as little of the sulphur as possible. This lye, after it had stood for some hours, was poured off clear, and had but a slight tendency to a green colour. I made a second infusion with milk-warm water, and poured it off from the sediment. This had a darker colour than the former, was kept separated from the former, and evaporated by itself. There was a third infusion made; but having no salt taste, it was thrown away. The second infusion seemed to contain more sulphur than the first; and a piece of white linen kept in it half an hour, while it was boiling, was tinged yellow, and could not be washed white again. The earthy part remaining, weighed, when well dried, 1 oz. 2 dr. The saline decoction, evaporated by degrees, and set at different times in a cellar to crystallize, afforded me 5 dr. 46 gr. The liquor, when entirely evaporated, left $4\frac{1}{2}$ dr. of a yellow salt,

SECT. VI. ON BLEACHING. 153

salt, which appeared to be a strong alkaline. The salts which crySTALLISED seemed to be mostly sea salt, with a considerable quantity of sulphur, and some alkaline salt. There appeared no signs of the bittern in these salts, as their solution did not turn turbid with the oil of tartar. Nor was any of the bittern to be expected in kelp ashes, although it probably is to be found in the recent vegetable; because the alkaline salts formed by the fire, must have changed it into a neutral. The lye made with warm water, being evaporated, left 4 dr. of a black bitter salt, which, from its quantity of sulphur, appeared unfit for bleaching. These ashes, then, seem to be a composition of somewhat less than the fourth of sulphur, the same quantity of sea salt, about a fourth of alkaline salt, and somewhat more than a fourth of earth. The alkaline salt contained in kelp ashes, amounts to one penny a pound. This cheapness makes it worth our pains to bestow some labour on them.

IF the bad effects in bleaching with kelp ashes arise from the sea salt, as some of the

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most knowing bleachers think, they can be freed from it in an easy manner. Let a lye of kelp ashes be made with cold water, for that does not extract so much of the sulphur; it must stand but a short time, for these salts dissolve easily; decant it, and evaporate the lye. As the boiling continues, the sea salt will crystallize. When that is all separated, the remaining lye will contain alkaline salt with some sulphur. This operation every master of a bleachfield may learn and oversee, without taking up much of his time. A similar process is carried on by common servants in the allum-works, who have by practice learned it from others.

I had some hopes that the sulphur might be carried off by long roasting, such as these salts undergo, before they are fused, in order to be turned into glass; because I had observed, that the longer time they were kept in the fire, the freer were they from this sulphureous part.

Exp. 53. I ordered a quantity of kelp ashes to be kept in the furnace of a glass-house,

Sect. VI. ON BLEACHING. 155

house, where the heat was just below the vitrifying point, for twenty-four hours. During this time they had lost almost four fifths of their weight. They were now much freer from their sulphur, and were of a light colour ; but much of the alkaline salt had been driven off with the oils. If a lye is much impregnated with this sulphureous matter, it appears to be carried off, in a great measure, by long boiling.

IF we cannot get these alkaline salts at home in sufficient quantity, our plantations are ready to afford them, if we are not wanting in industry. Our colonies would gain health and riches by the traffic, and we should be provided more certainly, and at a much cheaper rate. The hiccory wood, we are told, affords great plenty of this salt. The only way to set on foot such a trade as this, would be to send from this people skilled in the manufacture, with such proper encouragement, for a certain number of years, as the wisdom of parliament shall think fit.

WE come now to explain the method of manufacturing the white *Muscovy* ashes. We have shown, by undoubted experiments, that the greatest part of these ashes consists of lime; and yet we have several acts of parliament which forbid the use of that material under severe penalties. The parliament were in the right to discharge its use, upon the disadvantageous reports which were made to them. We shall immediately see, how dangerous a material it is when used improperly, or without the mixture of alkaline salts, which render it safe, and more soluble in water. But I'll venture to say, that experiment will not support the prejudice entertained with regard to it, if carried any further.

SINCE bleaching, then, cannot be carried on without it; for those ashes which contain it, are quite necessary in that operation; and since we import them from foreign countries; let these prejudices against it cease; and let us only consider how we may render our own lime as safe as the foreign. If we can do that, the wisdom of the legislature

lature will be as ready to abrogate these acts, as they were to make them.

By my experiments on the white *Muscovy* ashes, I got about the eighth part of alkaline salts from them. This made me expect, that, by mixing in the same proportion quick-lime and alkaline salts, I should be able to produce *Muscovy* ashes.

Exp. 54. To an ounce of quick-lime and a drachm of white pearl ashes, I added about a gill of water, and boiled them together till the water was all evaporated. The taste of this substance was little different from lime. To recover the salts again from the lime, I dissolved it in water, strained off the liquor, and evaporated it. Instead of the drachm of salts, I had but 2 gr. of a substance which was more earthy than saline.

Exp. 55. To 3 dr. of quick-lime, and as much potashes, I added a mutchkin of water, and kept it boiling for two hours till it was evaporated. I dissolved it again in
water,

water, which being filtered and evaporated, gave me $1\frac{1}{2}$ dr. of a caustic salt, that liquified in the air, when it had been but four minutes from the fire. It appears, then, that the alkaline salts are destroyed by lime, and that a great part of them can never be again recovered. They must be reduced to an unsoluble substance. From the remaining lime, after the salts were extracted, I got strong lime-water, but without a pellicle. This shows, that a quantity of alkaline salts, equal to the lime, boiled with it for two hours, are not able to fix all the soluble part of the lime.

FROM these experiments we may draw some corollaries with regard to the present subject. *1st*, That evaporating the water from the lime and salts by boiling, is a most unfrugal way of preparing these white ashes. *2^{dly}*, That these ashes ought to be kept close shut up in casks; for if exposed to the open air, though in a room, the alternate moisture and drought must fix their most useful parts. This I have found to be fact; for the salts that I made, became less
pungent

SECT. VI. ON BLEACHING. 159

pungent by keeping; and I have observed, that the surface of the *Muscovy* ashes lost all pungency, by being exposed to the air, while their internal parts still retained it. 3^{dly}, That all boiling is prejudicial to these *Muscovy* ashes, as it fixes, and that quickly, their most subtile, and probably their most serviceable parts.

LET us now proceed to another method of making these white ashes. I imagined, that if the salts were dissolved in water, and the quick-lime slaked with that, the mass would soon dry without the assistance of fire. In this way I added equal parts of both; but the composition was so strong, that it blistered my tongue, if it but touched it. When the fourth part was alkaline salt, it blistered my tongue, when kept to it a few seconds. I could taste the salts plainly in the composition, when they made but the thirty-second part of the whole.

I thought, when composed with the eighteenth part of salt, it had, when fresh made, just the taste and look of the *Muscovy*

covy ashes; nor could any person have distinguished them. This I once imagined was the proportion; but when I found that the saline pungency soon turned weaker by keeping, and that this composition would not afford the same quantity of salts that the *Muscovy* ashes did, I saw that a much greater quantity of salts was necessary. The proportion appears to be one of salt to four of lime, prepared in the last way. Three drachms of ashes prepared in this way, and kept for a fortnight, gave me but 15 grains of salt; which is but the half of what the *Muscovy* would have afforded. I find, if the quick-lime is first quenched, it does not fix the salts so much; and therefore is better, and cheaper. One drachm of potashes dissolved in a little water, and added to 3 drachms of quenched lime, gave me 44 grains of a very caustic salt. I prefer this method as the best.

THE manufacturers of this salt probably pour the lixive upon the lime, as they can know by its specific gravity what quantity of salts is in the water, and so save themselves

SECT. VI. ON BLEACHING. 161

themselves the expence of procuring the salts in a dry form.

THERE is now only one proof wanting to show, that these are as good as the foreign *Muscovy* ashes, viz. their answering as well in the bleachfield. I sent some that I had made to Mr *John Chrystie*, and had the following account of their effects in the bleachfield. "The small parcel of ashes which I got from thee, appear to be very good, and in all respects answer the purposes of the *Muscovy* white or blanch ashes. They are just what goes by the name of *Riga Muscovy* blue ashes; which are the best of that kind. I am so well satisfied of their answering, that if thou can furnish me with a parcel next season, I shall take them; and doubt not of bleaching my cloth full as well with them, as with those brought from abroad."

THE manufacture of the *Marcoft* and *Cashub* ashes remains yet to be explained. We have discovered, that both of them contain

tain sulphur, earth, alkaline salts, and lime; and differ in nothing, but in the *Cashub's* having more sulphur than the *Marcoft* ashes. We shall therefore consider them together.

WHETHER these two species of ashes are of any use in bleaching, may, and has already been disputed. I find they contain no other principles, the sulphureous part excepted, than the former ashes combined together. Why then should we expect any other effects from the same ingredients in the *Marcoft* and *Cashub* ashes, than what we have from either of the pearl and *Muscovy* ashes mixed together? The sulphureous principle in the former must have very bad effects; as I find by experiment, that it leaves a yellowness on cloth, that is very hard to be washed out. It is owing to this sulphureous principle, that linen, after it has been washed with soap, and is pretty well advanced in whiteness, is apt to be discoloured by lye if brought to boil: for by boiling the sulphureous part is extracted from these ashes, and the lye becomes of

SECT. VI. ON BLEACHING. 163

a deep brown colour. Daily practice, then, shows the disadvantage of this sulphureous principle. Besides, as sulphur unites itself, quickly and firmly, with alkaline salts, it must weaken, or altogether destroy a great quantity of these in the *Marcoft* and *Cashub* ashes, and so render them of no effect in bleaching. These two reasons seem to me sufficient to exclude them from the bleach-field; especially as, by increasing the other materials, we can attain, perhaps more speedily, the same end.

HOWEVER, as custom has introduced them into general practice, we shall consider how they are to be manufactured. Dr *Mitchell* has, in a very ingenious and useful paper, contained in the *Philosophical Transactions* for the year 1748, delivered an account transmitted to him by Dr *Linnaeus*, of the method of making potashes in *Sweden*. This account was contained in an academical dissertation of one *Lundmark* upon this subject at *Aboe* in *Sweden*. The substance of this account is, "That birch
" or alder is burnt by a slow fire to ashes,

“ and made into a paste with water. This
 “ paste is plaistered over a row of green
 “ pine or fir logs. Above that is laid,
 “ transversely, another row of the same;
 “ and that likewise is plaistered over. In
 “ this way they continue building and
 “ plaistering, till the pile be of a consider-
 “ able height. This pile is set on fire;
 “ and whenever the ashes begin to run, it
 “ is overturned, and the melted ashes are
 “ beat with flexible sticks, so that the
 “ ashes incrust the logs of wood, and be-
 “ come as hard as a stone.” This, in the
 Doctor’s opinion, is the method of making
 the potashes that come from *Sweden*, *Rus-*
sia, and *Dantzick*: and that there is no
 other difference betwixt the ashes made in
 those different countries, but that the *Rus-*
sian, containing more salt, must be made
 into a paste with a strong lye.

THERE would appear, by my experi-
 ments, a greater difference than this, be-
 twixt the *Swedish* ashes, if that is the true
 process, and those I have examined. I
 had discovered the greatest part of the *Mus-*

Sect. VI. ON BLEACHING. 165

covy ashes to be lime. I suspected it might enter into the composition of the *Marcoft* and *Cashub*; and have accordingly discovered it there. Without the same grounds, none would ever have searched for it. Whence then comes this lime? It must either enter into its composition, or arise from the materials managed according as the process directs. Let us examine this question thoroughly, as it is a question of great moment, and nearly concerns the manufacture of these salts.

THERE are two passages in chymical authors, that would induce one to believe a very caustic substance might arise from the terrestrial part of vegetables fluxed with the saline. Thus *Junker*, *Cineres ligni bitulini recentes, et per cribrum trajecti, si aqua humectantur, et globi, instar pomorum, exinde conficiantur, dum æstu intensiore globi exsiccantur, postea igni ejusdem ligni flammante candescunt, denique adhuc calidi aqua pura coquantur; lixivium filtratum, et ad consistentiam saturati lixivii evaporatum, adeo acre redditur, ut lanam injectam in mucum resolvet;*

vet ; sulphur quoque brevi solvere soleat, licet in frigidum lixivium conjiciatur. The other quotation is from Stahl. *Causticum fit alkali maritatum cum terra sua propria, cinere pingui, si cineres ex lignis nitrosis, e. g. bitulino, leviter humectati, denuo urantur flammeo igni, sal deinde mox elixetur et coaguletur* *.

Both these chymists, I believe, have formed this opinion, on discovering the caustic effects of these *German* ashes ; but have taken the process of making them on the faith of others. There is no person who has dealt in chymical operations, but must have found the effect of his experiments very different from what the chymists made him expect. I have often been deceived ; and therefore suspend my belief till my own experience can determine my opinion. I have tried the birch ashes made into a paste with water. I have tried common charcoal, made into a paste with a third part of potashes, and kept them in a strong reverberatory heat for some hours, and yet no such caustic substance appeared.

* Vid. Stahl Specim. Buchan. p. 11. f. 1. m. 1. N° 58.

Sect. VI. ON BLEACHING. 167

I have kept the earth and salts of kelp ashes fused together for twenty-four hours in the furnace of a glass-house, where the heat was but just below the degree of vitrification; and yet no remarkable causticity appeared, afterwards, in the concreted mass. But supposing that there did, will ever this account for the generation of lime? These chymists do not assert that it is a calcarious causticity. The earth of vegetables kept in fusion with their salts, is so far from turning into a quick-lime, that the mass takes the opposite course, and becomes glass. Bodies that, by the laws of nature, are vitrescible, can never, so far as we know, become calcarious. In one or other of these two substances all bodies terminate, that are changeable by fire; and vegetables are of the former kind. Here it may be asked, Why then, since they endure such a fire, are they not vitrified? The objection would be just, did they contain nothing else but what was found in vegetables. But if we once allow, that lime is one of the materials, the difficulty is easily solved: for lime, we know, in proportion as it is mixed, hinders

ders the vitrification of all bodies. In effect, the earthy part in these ashes is almost vitrified; and I think that I have carried the vitrification yet farther in that part; but I never was able, with the utmost heat of a reverberatory furnace, continued for six hours, to produce any thing like a thorough vitrification in these ashes. The heat of the fire used in the process, would seem to be very great; and must, if it were not very difficult, reduce them to glass. The invitrifiable nature of these salts, so far from being an objection, becomes a strong proof of my opinion.

THESE salts have a remarkable pungency. This we have already seen is the natural effect of quick-lime on salts.

THESE salts are found to be the fittest for making soap, and to incorporate soonest and best with oils. Salts, we know, of themselves do not readily unite with oil; but when once mixed with quick-lime, they have a greater tendency to union.

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SECT. VI. ON BLEACHING. 169

AGAIN, I find that these ashes are more easily fluxed than charcoal made into a paste with the third part salt; which is much more than these ashes contain. Now, it is observed, that quick-lime increases the fluxing power of alkaline salts; for the common caustic made of quick-lime and alkaline salts, is sooner fused than the latter alone.

FROM these reasons, and the experiments that discover lime in these ashes, I am led to think, that it is not generated by the process, but mixed with the ashes when they are made into a paste. The following experiment is a convincing proof of what I have been endeavouring to make out.

Exp. 56. I boiled some pease straw in a strong lye of pearl ashes, burnt it into a black coal, and made it into a paste with water. Another quantity of straw was boiled in a lye made of one part quick-lime, and four parts pearl salts, the lye being poured off turbid from the lime. This straw was likewise burnt when dry, and made in-

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to a paste. These two substances were put into separate crucibles, and fluxed in a reverberatory furnace. The latter appeared to resemble the *Marcoft* and *Cashub* ashes, more than the former, which seemed to want their pungency.

LONG after I was satisfied this was the way of manufacturing these northern ashes, I accidentally met with an observation of a knowing bleacher. Mr *Chrystie* says, that he was told by Mr *Robert Douglas*, who had been in *Russia*, *Sweden*, and many other parts, that he had seen the following method of making ashes practised. “ The
“ ashes of burnt wood or weeds were mixed with quick-lime, put into a fat or receiver, and a very strong lye was drawn from them by water, just as bleachers make their lye. In this lye dried wood or weeds were soaked, until they would imbibe no more, and then burnt in ovens prepared for that purpose. These ovens had a strong draught of air, which made the fire burn most furiously; and as the wood was fluxed in the fire, it fell
“ through

Sect. VI. ON BLEACHING. 171

“ through the grate, and run into hard
“ lumps.” These ashes, by this descrip-
tion, appear to be *Cashub*, or *Marcoft* ashes.
I would recommend this method as the
easiest and quickest of manufacturing these
salts at home.

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PART

P A R T IV.

S E C T. I.

The natural effects of these ashes, and other bodies, on unbleached cloth.

IT is no wonder, that the art of bleaching has, as yet, made such small advances, when the facts and circumstances are confined to the bleachers alone, and the natural effects of different bodies on cloth are, even to them, unknown. There are two causes, among many, to which the latter ought principally to be attributed. The generality of those who practise bleaching, look on it as a business already brought to perfection; and, being ignorant of natural philosophy, and the experimental method of carrying it on, never imagine the further progress which it could bestow on this art. The other cause which retards the progress of bleaching, is a want of accurate observations on the effects of the different agents which are employed in it.

And,

And, indeed, it is impossible that these observations should be made in the common course of business, considering how these ashes are mixed together, when used by bleachers, so that the particular effects of each can never be known; and considering how the other operations of this process immediately succeed those applications, by which the effects of all are blended together.

To remedy a defect which cannot well be obviated in the bleachfield, I have made a few experiments, in order to discover the effects of different substances on unbleached cloth. As this is but an attempt towards a complete set of experiments in bleaching, I hope they will excite others, whose proper business it is, and who have greater opportunities than I of pursuing the like researches. They will point out the general method to be followed in making such experiments. However disagreeable or tedious the plain narration of experiments may appear, there is no other way to arrive at truth; especially in an art where, from a deficiency in these, there is as yet but little certainty.

THAT

THAT I may make these experiments as accurate and extensive as possible, I shall try them with different degrees of heat; with that of the atmosphere, with a gentle degree of heat, equal to that of the human body, and with the heat of boiling water; for the effects of most dissolvents are increased by heat. The cloth used in the following experiments, was steeped in warm water for a night, to take out the dirt and dressing.

Exp. 57. July 26. To discover the effects of pearl ashes, I dissolved 10 gr. of pearl ashes in 6 oz. of water, and put a piece of unbleached cloth, about 15 square inches, into the solution. After it had been in this weak lixive about a minute, a great many air-bubbles arose to the surface. 28. Ten grains more of the salts were added, and more air-bubbles arose as before. The lixive had now a strong alkaline taste. *Aug. 7.* The lixive tastes much weaker. The cloth appears to have a redder cast than a piece of the same cloth in plain water. Thirty grains more of the salts were added. About

Sect. I. ON BLEACHING. 175

About half an hour afterwards a great many air-bubbles were on the surface of the liquor, and many more arose on touching the glass.

9. I immersed the glass half-way up in warm water, and kept it there for two hours and a half, renewing the warm water.

During that time I saw no air-bubbles arise.

26. The water had no alkaline taste, and the cloth had a deep red colour. 28. That

I might see the natural colour of the cloth, and discover its degree of firmness, I took out the alkaline salts, by steeping the cloth all night in water acidulated with spirit of nitre. I could observe no fermentation or intestine motion in the liquor. The cloth,

being washed in warm water, and dried at the fire, appeared much whiter than when it was put into the lixive. I shall distinguish

the colours in the following experiments, at this particular time, into four different classes, according to their different degrees of whiteness, placing the whitest in the first class. According to this distribution of colours, the cloth in this experiment was in

the third class; it seemed as firm and strong as at first. Sept. 9. The cloth was taken

out,

out, washed with soap and water, and dried. There was not such a distinction betwixt the colours of the different cloths at this inspection as there was at the last; but still this cloth was inferior in colour to the rest. 21. There appeared a great sediment at the bottom of the glass. When the cloth was washed and dried, it was amongst the darkest-coloured, though whiter than at last inspection. It is still strong. I renewed the water, and added half an ounce of pearl ashes, to discover if these salts could weaken cloth. Nov. 11. The cloth appears no whiter, and no weaker.

Exp. 58. July 26. To discover the effects of *Muscovy* ashes, I added half a drachm of white *Muscovy* ashes in powder, to 6 oz. of water; and infused, in this mixture, the same quantity of cloth, as in last experiment. 28. I added the same quantity as before. The cloth just begins to whiten. *Aug. 9.* The glass stood two hours and an half in warm water. 26. The water had scarcely any taste. 28. The cloth was steeped all night, with the former, in water acidulated

Sect. I. ON BLEACHING. 177

acidulated with spirit of nitre. When dried, it appeared to be in the same class of colours with the former. It was remarkably weaker, so that I could easily tear it, when I could not the former. *Sept.* 9. Washed with soap, and dried, it now appeared to be in the first class of whiteness; still weaker, but not so much as the cloth, in shell-lime water. 21. Much whiter, but scarcely any weaker. *Nov.* 11. Not so white as the cloth in the lime-water, nor so weak.

Exp. 59. *July* 26. To discover the effect of *Marcoft* ashes, I boiled a drachm and a half of *Marcoft* ashes for half an hour in 6 oz. of water, adding, at the latter end, as much water as was lost by evaporation. Boiling is necessary to extract the salts from these ashes. In this lixive the same piece of cloth as in the former, was infused. *Aug.* 7. No whiteness yet begins to appear; the cloth seems rather somewhat reddish. 9. When the glass was put into milk-warm water, as the former were, air-bubbles arose. 28. The cloth was steeped all night

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178 EXPERIMENTS Part IV.

in water, acidulated with spirit of nitre. When dried, it appeared in the third class as to whiteness; it seemed considerably weaker. *Sept. 9.* Whiter and weaker. 21. Very white, but quite rotten. *Nov. 11.* Scarcely so white as the cloth in the two following experiments, but almost as rotten. *Cashub* seems, by experiment, to have much the same effect as *Marcoft*, in weakening cloth, but leaves a much redder colour on it.

Exp. 60. July 16. To discover the effects of lime-water, I infused the same quantity of the same cloth in stone-lime water. It sent up directly a great many more air-bubbles than any of the rest. *Aug. 7.* The cloth begins to appear whiter. No sediment to be seen. As the lime-water had almost lost its taste; all the glasses being but slightly corked, I renewed the lime-water. 9. The glass was put for two hours and a half in milk-warm water, during which a few air-bubbles arose. 26. Not much whiter than last time. A
brown

Sect. I. ON BLEACHING. 179

brown substance at the bottom of the glass.

28. Steeped the cloth for a night in water, acidulated with spirit of nitre, to take the particles of lime out of it. When dried, the cloth appeared to be amongst the whitest in the third class of colours. I did not yet discover it weaker. Renewed the lime-water. *Sept.* 9. When washed with soap, and dried, it equalled the cloth that had been steeped in the *Muscovy* ashes, and surpassed all the rest. It seems weaker.

21. It appears now very white, and very tender. Renewed the lime-water. *November* 11. No whiter, but rather weaker.

Exp. 61. *Aug.* 10. That I might discover what effect oyster-shell lime-water would have on cloth, as it has a stronger power in dissolving the human calculus than stone-lime water, I steeped the same quantity of the same cloth in the same quantity of shell-lime water. 26. Remarkably whiter, even more so than the cloth in the stone-lime water, that had been steeped double the time. 28. To take out the particles of lime, it was infused for a

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night

night in water, acidulated with spirit of nitre. When dried, it appeared rather whiter than the cloth of the former experiment, and as much weakened. Renewed the shell-lime water. *Sept.* 9. When washed with soap and water, it appeared whiter, but with a yellowish cast. It was much tenderer than the cloth of the former experiment. 21. Exceeding white, though with a yellow cast, but quite rotten. *November* 11. No whiter, but very weak.

Exp. 62. *July* 26. That I might discover the effects of alkaline salts and lime combined together, I flaked half a drachm of quick-lime with an equal quantity of pearl ashes dissolved in water. In this mixture an equal quantity of the same cloth as in the former experiments, was steeped. Some air-bubbles arose immediately. *August* 1. Some clouds were suspended in the liquor; and a filmy oozy matter was deposited at the bottom. 7. The cloth appears whiter. The lixive tastes yet very strong. 9. I added the same quantity of lime and salts, as the lye was beginning to
turn

Sect. I. ON BLEACHING. 181

turn weak. The glass was two hours and a half in milk-warm water, during which time many air-bubbles arose. 26. The lye tastes much weaker. 28. Steeped all night in the same acidulated water as the former were, and dried. This cloth was now the whitest of the whole, though it did not appear so before it was steeped in the acid. It is therefore to be ranked in the first class at present. Appears to be no weaker. Added to the liquor 5 gr. of the caustic salt extracted from equal parts of quick-lime and alkaline salts, and therefore of the same kind with the former. Sept. 9. The cloth washed with soap, and dried. Whiter than before; yet was scarcely so white as the cloth in lime-water, or that in the *Muscovy* ashes. 21. The cloth has now attained a very great degree of whiteness, and seems no weaker than when it was first put into the lixive. Nov. 11. As white as the cloth in the lime-water, and as strong as cloth that has been bleached in the safest way.

Exp. 63. July 26. To discover what effects lime-water with a few grains of alkaline

line salt would have on unbleached cloth, as this would be a cheaper method of bleaching than any of the former, I added to 6 oz. of stone-lime water, 10 gr. of blue pearl ashes. When the salts were added, the liquor turned white, curdled as hard water does with soap, and in a little a great quantity of white powder was precipitated to the bottom. Into this mixture the same quantity of the same unbleached cloth was put.

28. The liquor tasted like a weak solution of soap. *Aug. 1.* A small quantity of a filmy matter appears swimming in the mixture.

7. No whiteness yet appears. 9. Was two hours in warm water. 26. Tastes still pretty strong. 28. Steeped all night in the acidulated water, and dried. Appears now in the second class of whiteness; and though not so white as the cloth in the former experiment, yet surpassing all the rest. *September 9.* The cloth washed with soap, and dried. Though whiter than before, yet is not so white as that in the lime-water, or *Muscovy* ashes. Appears to be no weaker.

21. Is now very white, and a very little weaker. The liquor renewed. *Nov. 11.*

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Sect. I. ON BLEACHING. 183

This cloth appears as white as those in the stone and oyster-shell lime-waters. It seems to be no weaker than cloth that has been bleached in the best manner.

Exp. 64. July 26. To discover the effects of oil of vitriol, the same quantity of the same cloth was put into the same quantity of water, to which were added 30 drops of the oil of vitriol. 28. Added 30 drops more. The water has a gentle acid taste. *Aug. 1.* A white sediment, or oily-like matter lies at the bottom of the glass. 7. The liquor has no acidity. An oozy matter, similar to what was before observed at the bottom, is now to be seen floating in the liquor, and adhering to the cloth. The colour of the cloth is whiter than a piece of the same that had been for the same time in water. Sixty drops more were added, and the glass is put four hours in milk-warm water; during which a great many air-bubbles arose, and the liquor afterwards tasted much less acid. Cloth still firm. Sixty drops more added. 14. Covered all over with the oozy oily-like matter.

matter. 25. Appears whiter, with more of that oozy matter. The liquor is less acid. The cloth still strong. Renewed the water, and added 100 drops to it. 28. That I might take the acid salts out of the cloth, and discover its real colour, I steeped this cloth, and that of the two following experiments, in a solution of alkaline salts. I observed a fermentation, or intestine motion, in the liquor. When the cloth was washed and dried, it was much behind those in the foregoing experiments in colour, and but just a degree whiter than a piece of the same cloth that had been in plain water. It looked whiter when in the glass. It must therefore be placed in a fourth class. This cloth, and the two pieces in the following experiments, felt hard and rough. *Sept.* 9. Washed with soap and water. It was still much behind the former in colour. As strong as at first. *Nov.* 11. Colour and strength the same.

Exp. 65. *July* 26. To try the effect of spirit of nitre, the same quantity of the same cloth was steeped in the same quantity

Sect. I. ON BLEACHING. 185

tity of water, to which were added 30 drops of the spirit of nitre. The liquor tasted gently acid. Immediately after the cloth was put in, it was all full of air-bubbles.

28. The air-bubbles still adhering to it.

Added 30 drops more. *Aug.* 1. A white sediment lying at the bottom. 7. Not so

much of that oily-like matter, which was suspended in the former. Less acid than what it was before, and about the same degree with that of the former experiment.

A small degree whiter than the cloth in plain water, but not so white as the cloth in the vitriol. 8. The glass immersed half-way in milk-warm water for four hours. More

air-bubbles arise from this glass than from any of the others. That part of the cloth

that was below the surface of the warm water, seemed, after the glass was removed, to be whiter than that above the surface.

As the liquor tasted less acid, 30 drops were added. The cloth still firm. 26. The

liquor more acid than the vitriolated liquor in the foregoing experiment. The cloth as

white and as strong, but not so much of the oozy matter as in that. Renewed the wa-

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ter with 100 drops of the spirit. 28. After being steeped all night in the lye with the former, it appeared rough and hard, and of the same colour with it. *Sept. 9.* After being washed with soap and water, of the same colour as the former. As firm as at first. *Nov. 11.* Colour and strength the same.

Exp. 66. July 26. To discover the effects of the spirit of sea salt, the same quantity of the same cloth was steeped in the same quantity of water, and 30 drops of the spirit of sea salt. The cloth was immediately covered all over with air-bubbles. 28. Liquor still acid. Added 30 drops more. *Aug. 1.* This liquor is the most acid of the three. A white sediment at the bottom, but not so much as any of the former. 7. More acid than the vitriol, but less of the oily-like matter suspended in it. Added 30 drops more. A degree whiter than the cloth in plain water, but scarcely so much as that in the vitriol. 8. The glass was four hours in warm water; during which time many air-bubbles arose, and afterwards

Sect. I. ON BLEACHING. 187

terwards the liquor was less acid. That part of the cloth that was in the warm water, and had sustained the greatest heat, was whiter than the upper part. Cloth firm. Added 30 drops. 26. Not so white as the former two. No oozy matter at bottom. The liquor very acid. 28. When treated as the former, was as rough, and scarcely so white. As the glass was broke at this time, I added 60 drops to the same quantity of water. *Sept.* 21. Whiter, but no tenderer. The liquor is scarcely acid. Added 100 drops more. *Nov.* 11. Colour and strength the same.

THAT I might see what effects plain water had upon cloth, and, by that, more certainly judge of the real effects of these alkaline and acid salts,

Exp. 67. *July* 26. I put the same quantity of the same cloth in the same quantity of plain water. *Aug.* 1. Water begins to smell. A filmy oozy matter at the bottom. 7. Water spoiled, so renewed. 8. When in the milk-warm water, some air-bubbles arose,

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rose, but fewer than in the rest. 26. Renewed the water. *Sept.* 9. The cloth had a yellow cast. 21. A very little whiter, but no tenderer. *Nov.* 11. Whiter.

To discover if soap has any power in whitening unbleached cloth more than removing the dirt on the surface,

Exp. 68. *Sept.* 9. Forty-four grains of the same cloth was steeped in 8 oz. of water, in which was dissolved 2 dr. of *Castile* soap. *Nov.* 11. The cloth was of the same colour and strength as when put in; and, when washed and dried, weighed 45 gr.

THAT I might discover the effect of sea salt on unbleached cloth,

Exp. 69. *Aug.* 30. I dissolved half a drachm of pure sea salt, without any mixture of the bittern, in 6 oz. of water, and infused a piece of cloth in it. *Sept.* 21. Cloth a degree whiter, but no tenderer. *Nov.* 11. The cloth appears rather darker than when put in, and is remarkably thinner

Sect. I. ON BLEACHING. 189

ner and weaker. There is much black matter at the bottom of the glass. As I imagined that these effects proceeded in some measure from corruption, which is aided by a small quantity of sea salt, I repeated this experiment twice, once with 2 dr. and once with 4 to the same quantity of water. After they had stood eight weeks, the cloth in each appeared thinner, weaker, and no whiter.

THAT I might discover the effect of putrefaction on cloth,

Exp. 70. Aug. 8. A piece of the same cloth was put in water. 26. Water much spoiled, and the cloth very black. 30. The cloth still blacker, and some black matter like foot, has fallen to the bottom of the glass. There is a pellicle on the surface of the liquor. The cloth, when dried, was no weaker. *Sept. 9.* The water stunk abominably, and the cloth as black as foot before washing, but was not sensibly weaker. *Sept. 21.* Still black, but no weaker. The quantity of black precipitated matter increased.

creased. *Nov. 11.* The cloth washed with soap and dried, appears a very little darker, with some yellow clouds in it, and is much weakened.

My next experiments were made with a view to discover what effect a gentle degree of heat, equal to that of the human body, would have on the action of these bleaching materials.

Exp. 71. Aug. 10. The same quantity of the same cloth was steeped in the same quantity of water, in which 40 gr. of white pearl ashes had been dissolved, and set so near the kitchen-fire, as to keep it in the forementioned degree of heat. 14. The cloth was whiter. 28. Steeped all night in the same acidulated mixture with the others, and dried it. Appeared much whiter, and was at present next to the cloth in the lime and ashes of those four experiments made with this degree of heat. *Sept. 9.* Whiter than the following experiment made with the oil of vitriol. 21. Whiter, and still stronger. Added 40 gr. more. *Nov. 11.* No whiter, and no weaker.

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Sect. I. ON BLEACHING. 191

Exp. 72. Aug. 10. The same quantity of the same cloth was infused in the same quantity of stone-lime water, and that the fire might not soon evaporate the lime, 2 tea-spoonfuls of fine flaked lime was added. 14. Begins to whiten. 28. The cloth not so white as in the last experiment at this time. *Sept. 9.* This was now the whitest of those that stood at the fire, and much more so than the cloth of any of the experiments made without any heat, but is very tender. 21. The whitest of the whole, but so tender, that it separated with the least force. *Nov. 11.* The cloth is now so rotten, that it has fallen all to pieces in washing it, and can be reduced, betwixt the fingers, to a powder.

Exp. 73. Aug. 10. The same quantity of the same cloth infused in the same quantity of water, to which was added 1 dr. of home-manufactured *Muscovy* ashes, viz. 4 parts of quick-lime flaked, with 1 part pearl ashes and water. 14. Begins to whiten. 28. This cloth was now the whitest of all those at the fire. *Sept. 9.* Neither so white
nor

nor so weak as the cloth in the former experiment. 21. Very white and tender. Nov. 11. Quite rotten, though not so much as the former.

Exp. 74. Aug. 10. The same quantity of the same cloth in the same quantity of water, to which was added 95 drops of the oil of vitriol. 14. Whiteness just begins to appear. Added 70 drops more. 28. The least advanced of the whole at the fire in whiteness. Sept. 9. It had now a deep reddish cast. 21. Much whiter, but no weaker. Nov. 11. The cloth has got a reddish colour, and is no weaker.

LET us now see the effect of these salts when the heat employed arises to that of boiling water.

Exp. 75. Sept. 11. Three drachms of unbleached cloth, at 13 *d.* a-yard, was put into a pint of water, in which was dissolved 1 dr. of pearl ashes, and the water gradually brought to boil. It was kept boiling for five hours, having filled it twice up with water.

Sect. I. ON BLEACHING. 193

water, as the boiling diminished it. When it had boiled two hours, the decoction had no longer any taste of the salts, and was high coloured. When the five hours were elapsed, the cloth was taken out, wrung, and well washed in warm water. When dried, it was still firm and strong, and weighed 2 dr. 50 gr.: so that it had lost 10 gr. Being exposed to the influence of the air all night, and next day, which was very hot and clear, and regularly watered as it dried, the cloth lost $3\frac{1}{2}$ gr. *Sept. 13.* Boiled as before in a fresh lye, wherein 1 dr. of pearl ashes was dissolved. When it had boiled two hours, I added 1 dr. more. Five hours after that 1 dr. more was added. It was removed when it had boiled thirteen hours; at which time the lye tasted strong; washed, and dried. The cloth was still firm, had a yellow colour, and weighed 2 dr. 40 gr. So that it had lost $6\frac{1}{2}$ gr. on this last boiling. In order to discover what quantity of the saline particles remained in the cloth, I steeped it in water and vinegar, equal parts, for half an hour. When the cloth was first put in, there was a great fermentation,

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mentation, or intestine motion, and many air-bubbles arose. Washed and dried, it was 2 gr. lighter. During the 14th, 15th, and 16th of *September*, it was exposed night and day, and watered. Washed and dried, the cloth weighed 2 dr. 33 gr. *Sept.* 17. The same cloth was put into the last decoction, as it was yet strongly alkaline, to see if these salts could weaken it. Having boiled eleven hours, it was taken out, washed, and dried, and weighed 2 dr. $38\frac{1}{2}$ gr. So that it had gained 5 gr. from the foul decoction. It was now about the strength of cloth that comes from the bleachfield; and though not tender, yet was weaker than at first. To carry off the foulness and salts that it had absorbed from the lye, and discover its real diminution, I put it in vinegar for three minutes. Air-bubbles arose. Washed and dried, it weighed 2 dr. $30\frac{1}{2}$ gr. I now discovered that the last boiling had extracted $2\frac{1}{2}$ gr. from it. Exposed from twelve to seven at night in a strong wind, but no sunshine, and watered twice, it weighed 2 dr. $28\frac{1}{2}$ gr. *Sept.* 20. The cloth was put into butter milk, that had been well skimmed, and

Sect. I. ON BLEACHING. 195

and soured by boiling with a little water, so that it was now very thin, and as sour as good vinegar. Some air-bubbles arose. 22. The whey no longer sour. 24. The cloth taken out, washed in warm water, and dried, weighed 2 dr. $33\frac{1}{2}$ gr. So that it has gained 5 gr. of additional weight from the butter milk.

Exp. 76. Sept. 12. Two drachms fifty-two grains of the same cloth were boiled as the former, with 1 dr. of *Muscovy* ashes, for five hours. When washed and dried, it weighed 2 dr. $46\frac{1}{2}$ gr. The *Muscovy* ashes had been kept by me for four months, and they seemed to me not to be very strong. The colour was like the former. Exposed in a cloudy but warm day, I observed, that when dry, it did not imbibe the water that was thrown on it, but allowed the water to run off as if the cloth had been oiled; and when I thought the cloth was sufficiently wet by watering it, I found the opposite side almost dry. It was exposed for twenty-four hours. When dried, it weighed 2 dr. 43 gr. The cloth was divided into two dif-

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ferent pieces, which weighed 1 dr. 21 gr. each. To try what effect *Castile* soap has in the lye, and if it corrects the corroding quality of the *Muscovy* ashes, I put one half, which I shall call N° 1. into an *English* pint of water, to which was added 1 dr. of *Muscovy* ashes; and N° 2. into the same, with an addition of half a drachm of *Castile* soap. After they had boiled two hours, 1 dr. of *Muscovy* ashes was added to N° 1.; and the same, with the addition of half a drachm of *Castile* soap, to N° 2. Five hours afterwards the same addition was made to each. After they had boiled thirteen hours, both pieces of cloth were taken out, washed, and dried. Both pieces were much weakened: if there was any difference betwixt them; N° 2. was most so. N° 1. weighed 1 dr. 16 gr.; N° 2. 1 dr. 18 gr. Both pieces exposed to the air, and watered, for twenty-four hours, then dried, N° 1. weighed 1 dr. $12\frac{1}{2}$ gr.; N° 2. 1 dr. 15 gr. Sept. 16. Put both pieces in a pint of butter milk. 24. The milk is whigged, and still pretty four. Took out both pieces, washed

Sect. I. ON BLEACHING. 197

washed and dried them. N° 1. weighed 1 dr. $12\frac{1}{2}$ gr.; N° 2. 1 dr. 14 gr.

Exp. 77. Sept. 12. One drachm and a half on the same cloth was boiled as the former, with 1 dr. of *Marcoft* ashes, for five hours. When washed and dried, it weighed 1 dr. $21\frac{1}{2}$ gr. The cloth was whiter, but had a yellow cast. *Sept. 13.* Laid out to dry at ten *a.m.* in a cloudy day. This cloth, when dry, quickly imbibed the water that was thrown on it. This exposed for twenty-four hours in cloudy weather, seemed the whitest of all the pieces that were boiled. Taken up *Sept. 16.* in the evening, it weighed, when well dried, 1 dr. 18 gr. and was still firm and strong. The cloth was steeped in an acid liquor, consisting of two parts water and one part vinegar. Taken out *Sept. 18.* washed, and dried, it weighed 1 dr. $17\frac{1}{2}$ gr. When boiled in half a pint of water, and 2 dr. of *Marcoft* ashes, for thirteen hours, washed and dried, it weighed 1 dr. $12\frac{1}{2}$ gr. The cloth was as strong as at first. Exposed in sunshine, and a good gale of wind, from nine

a.

a. m. to seven *p. m.* and watered four times during that time, it weighed 1 dr. 15 gr. The water that I used in these experiments, was in the second class of hardness, and might therefore have left some particles behind in the cloth, or the wind might have blown some dust upon it. This cloth has now attained a considerable degree of whiteness, and appears to be a little weaker. Soured in the same butter milk whigged, as is described in *Exp.* 75. for four days, then washed in warm water and dried, it weighed 1 dr. $13\frac{1}{2}$ gr. It seemed now to have again recovered all its strength.

Exp. 78. *Sept.* 11. Boiled $2\frac{1}{2}$ dr. of the same cloth the same way as in the former experiments, in an *English* pint of water, and 50 gr. of quick-lime. After it had boiled five hours, the decoction tasting strongly of lime-water to the last, the cloth, when washed and dried, weighed 2 dr. 8 gr. so that it had lost 22 gr. of its weight; and if we allow that some of the lime might still be in the cloth, it must have lost more. It was evidently thinner, and scarcely so white

Sect. I. ON BLEACHING. 199

white as the cloth boiled the same time in the pearl ashes. Exposed to the air for twenty-four hours, the day being very clear and very hot, it lost $1\frac{1}{2}$ gr. Sept. 13. This cloth was boiled for thirteen hours, adding 50 gr. of lime at proper intervals, as in the former cases. When washed and dried, it weighed 2 dr. $5\frac{1}{2}$ gr. Appeared remarkably whiter, weaker, and was full of white dust, which appeared whenever the cloth was shaken or tore. To discover what quantity of the lime it contained, it was steeped in warm water and vinegar, washed and dried; it weighed 2 dr. 1 gr. It seemed now considerably softer, and thinner, and was not easily wetted by the water which was thrown on it.

Exp. 79. Sept. 12. To discover the effect of pearl ashes and lime mixed together, 3 dr. of the same cloth was boiled in an *English* pint of water, and pearl ashes, and quick-lime, half a drachm each, for five hours. The cloth, when washed and dried, had a reddish colour, and weighed 2 dr.

44 gr.

44 gr. Exposed directly to the air, watered for four days, and dried, it weighed 2 dr. 36 $\frac{1}{4}$ gr. No weaker. That I might take all the alkaline particles out of it, the cloth was steeped in fresh churned milk and water, equal parts, for forty-eight hours. It weighed, when washed and dried, 2 dr. 39 gr. It was boiled for thirteen hours in quick-lime and pearl ashes, 3 dr. each, adding them at proper intervals, as in the former experiments. The cloth, when washed and dried, weighed 2 dr. 18 gr. It seemed weakened, but not so much as in the last experiment. Sept. 20. Steeped in the four whig of butter milk for four days. It weighed, when washed and dried, 2 dr. 15 $\frac{1}{2}$ gr.

To discover the effects of pearl ashes mixed with the *Muscovy* ashes as they are in the bleachfield,

Exp. 80. *Sept.* 12. I boiled 3 dr. of the same cloth in a pint of water, to which were added 40 gr. of *Muscovy* and 20 of pearl ashes, which I computed to be nearly
of

Sect. I. ON BLEACHING. 201

of the same strength as equal parts of quicklime and salts. When it had boiled five hours, was washed and dried, it weighed 2 dr. 32 gr. Exposed to the sun at two *p. m.* and watered, and taken up *Sept.* 16. in the evening, it weighed 2 dr. 27½ gr. The water did not penetrate it well. No weaker. To see if any alkaline particles yet remained in the cloth, it was steeped in water and vinegar. When dried, it weighed 2 dr. 23 gr. *Sept.* 24. Boiled for twelve hours in 3 dr. of pearl ashes and as much *Muscovy*, adding 1 dr. of each at proper intervals, as in the former experiments; when washed and dried, it weighed 2 dr. 39½ gr. The cloth boiled in the quicklime and pearl ashes, and that in the *Marcost* ashes, were the whitest of the last six experiments. The other four pieces were pretty much of the same colour. The cloth appeared to be much of the same strength as that in the last experiment.

To discover the effects of the mineral acids with a boiling heat,

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Exp.

Exp. 81. Sept. 18. I boiled 42 gr. of the same cloth in a half *English* pint of water, to which were added 2 dr. of the spirit of vitriol. After it had boiled five hours, the water was still acid. The cloth, when washed and dried, weighed 38 gr.

Exp. 82. To try the effect of soap, I boiled 39 gr. of the same cloth in half a pint of water and 1 dr. of *Castile* soap. The water was kept boiling for five hours. The cloth, washed and dried, weighed $38\frac{1}{2}$ gr. It had therefore lost only half a grain during five hours boiling.

To see what effect plain boiling water would have on cloth, that I might not attribute what belonged properly to it, to the different bodies that I have been trying,

Exp. 83. Forty-two grains of the same cloth were boiled, as the others had been, for five hours in water. When dried, it weighed $41\frac{1}{2}$ gr. It had got something of a yellow colour, and was evidently weaker; for

Sect. I. ON BLEACHING. 203

I tore it, but indeed with some difficulty, which I could not do before it was boiled.

ALTHOUGH it is the practice with bleachers to mix soap with their lye, yet the necessity or utility of it is still a doubtful question. In defence of the common practice, it is said, that the soap blunts the sharpness of the salts, and makes the lye more safe. On the contrary, it is alledged, that making the lye weaker would have the same effect, and the soap would be saved. This question is only to be determined by experiment.

Exp. 84. Sept. 11. Forty-five grains of unbleached cloth were infused in a pint of lime-water. *Nov. 15.* Cloth is much weakened, and weighs $43\frac{1}{2}$ gr.

Sept. 11. I put the same quantity of cloth in the same quantity of lime-water, with the addition of half a drachm of *Castile* soap; which broke in it as in hard water. *Nov. 15.* The soap still swimming on the top; and the cloth as weak as in the former case, but feels softer.

Sept. 11. Forty-four grains of the same cloth were put in a pint of water, to which were added 2 scrup. of *Muscovy* ashes and half a drachm of *Castile* soap. In this the soap dissolved tolerably well. *Nov.* 15. Cloth weaker, and weighs 41 gr.

Sept. 11. Forty-five grains of the same cloth were put in the same mixture, with the addition of half a drachm of pearl ashes. *Nov.* 11. The cloth as white as the former; is not weakened, and weighs 42 gr.

It appears, then, that the corroding power of lime and *Muscovy* ashes is not weakened by soap.

THAT I might see if soap had any effect on lime and salts mixed in equal quantities,

Exp. 85. *Sept.* 23. Sixteen grains of cloth were put into 2 oz. of water, in which was dissolved half a drachm of salts, that had been procured from equal parts of quicklime and pearl ashes. The same quantity of cloth was put into another mixture of
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Sect. I. ON BLEACHING. 205

the same kind, with the addition of half a drachm of soap. *Nov. 15.* Both pieces of an equal colour, both strong, and both had lost 1 gr. That in the soap was softest.

I have in these experiments related the facts as they appeared to me, and not the conclusions which may be drawn from them. Experiments, and the reasonings on them, ought, in my opinion, always to be kept separated, that every one may have it in his power to judge, whether the latter naturally and justly arise from the former. Let us now see what aphorisms or corollaries may be fairly drawn from the foregoing experiments. I could wish more of these had been made, that those might have been established with a greater degree of certainty. I endeavoured to supply their number by their accuracy; for these experiments were all repeated a second time. The first accounts of all arts and sciences, have ever been imperfect; that will be excuse sufficient for what failings are met with here. But let it be remembered, that these first rude attempts have pushed on and helped others

others to bring these arts to greater perfection.

Corol. 1. Water appears by *Exp. 67. & 81.* to dissolve something in the cloth, to make it lighter, and to have a power, though a weak one, to whiten cloth. If brought to boil, it would seem to have a tendency to weaken cloth. Water, then, may justly be ranked amongst the bleaching menstrooms.

Cor. 2. The mineral acid spirits, *viz.* oil of vitriol, spirit of nitre, and spirit of sea salt, when diluted with a sufficient quantity of water, extract from the cloth somewhat of an oozy substance, heavier than the acid mixture, as most of it falls to the bottom; whiten cloth, though not strongly; and do not weaken it. The oil of vitriol whitens most, spirit of nitre next, and spirit of sea salt the least of the three. They likewise make the cloth rough and hard.

Cor. 3. Pearl ashes extract something from the cloth; send up a considerable quantity of air-bubbles during the solution; make

make it whiter, though with a yellow cast; but do not seem to have any tendency to weaken cloth when kept in the lye. Their power of whitening is stronger than that of the mineral acids, but not so strong as lime, or a mixture of lime and pearl ashes. I never could discover that they weakened cloth in the least, although it was dried with the lye in it. This is contrary to the general opinion. The reddish colour that the lye acquires, and gives to cloth, arises from the particular action of alkaline salts on the juice of vegetables: for it will appear afterwards, that lint steeped in water, affords a pale-coloured tincture; but whenever alkaline salts are added to it, the tincture becomes red. The colour, then, is no sufficient proof of the strength of such tinctures as are drawn with alkaline salts.

DR *Hales* has observed, that alkaline salts, though they have no effect on the hard calculi formed in the human bladder or kidneys, will dissolve the soft stones that are found in the gall-bladder.

Cor.

Cor. 4. *Muscovy* ashes have a remarkable power in whitening cloth, but they weaken it much. A bleacher told me, that he once attempted to bleach with these ashes alone, but all his cloth was soon eat into holes.

Cor. 5. *Marcoft* ashes extract more from the cloth, whiten it more, and weaken it less, than *Muscovy* ashes do when used in the same quantity. The cloth in *Exp. 59.* was rather weaker than that in *Exp. 58.*; but there was a half more of the *Marcoft* than of the *Muscovy* ashes. *Cashub* gives cloth a redder dye than the former, and weakens it as much.

Cor. 6. Stone-lime water whitens more, though it gives the cloth a yellow cast, weakens more, and extracts more out of the cloth, than any of the former materials. This is sufficient to deter any person from using this material by itself.

Cor. 7. Oyster-shell lime water enjoys all these properties in a much stronger degree than the stone-lime water; and therefore
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Sect. I. ON BLEACHING. 209

ought to be deemed the most expeditious, but most dangerous material for bleaching that is yet known.

Cor. 8. Alkaline salts added to lime, diminish its power of weakening and corroding cloth ; and that in proportion to the quantity of these salts added to the lime. This composition, as it is not so dangerous as lime alone, so it is not so expeditious in whitening. When equal parts of each are used, the whitening power is strong, and the weakening power not very considerable ; so that I imagine they might be used with safety, in the proportion of one part of lime to four of pure alkaline salts, to bleach cloth. This fully accounts for an observation made by all bleachers, That the bleaching salts, when mixed together, operate safer and better, than when used separately. For the corrosive power of the *Muscovy*, *Marcoft*, and *Cashub* ashes is corrected by the pearl ashes, and the whitening quality of the latter is increased by that of the former.

THERE is not a more corroding substance,
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stance, with regard to animals, than alkaline salts and lime joined together, especially when fused in the fire. This is the composition of the common caustic. But lime, and lime-water alone, preserve animal substances in a sound entire state. It appears then very surprising, that salts and lime should be found so little destructive to cloth, when lime, or lime-water alone, destroy it so remarkably. And yet this appears perhaps stronger than any other fact, from the whole of the foregoing experiments. So dangerous it is to depend altogether on analogical reasoning.

THIS corollary is further confirmed, if that is necessary, by a paper which, by accident, fell into my hands long before I had made these experiments. It lays down a method of bleaching safely with lime, as practised by the person who wrote it. My prejudices were so strong against the use of lime, in any shape, before I had tried these experiments, that I had not then so good an opinion of the method, as I now have. As
it

it contains many judicious observations, I shall give it as it was delivered me.

Method of bleaching with lime.

“ *First*, I steep the cloth in warm wa-
 “ ter for twenty-four hours, then clean it
 “ in a washing mill, of all the dressing, or
 “ sown, as the vulgar term it. After-
 “ wards I buck the cloth with cow-dung
 “ and water, and bleach it with this for
 “ three days ; then clean it again, and boil
 “ it with a lye made of *Caskub* ashes. A
 “ pound to each piece of 18 or 20 yards long
 “ is sufficient. This I do twice, as no lime
 “ ought to be given to cloth before it is a
 “ full third whitened ; as it by no means
 “ advances the whitening of the cloth,
 “ but, on the contrary, protracts it : for, in-
 “ stead of loosening the oil and dirt in the
 “ cloth, when brown, it rather fixes them ;
 “ just as when fine cloth is bucked with o-
 “ ver-warm lyes in the first buckings.
 “ Lime is by no means fit for discharging
 “ the oil in the cloth, but for cleaning
 “ it of the dead part, commonly called

sprat. The cloth being cleaned, is
laid upon a dreeper. It must not be
drier before bucking with lime, other-
wise it will take in more than can be got
out again before the next application:
for as I have observed already, that lime
is only fit for discharging the dead
part, bucking thus wet makes it rest
on the outside of the cloth. I take
a lippy of the finest and richest powder-
ed lime that can be got, of the brightest
white colour, as poor lime does more
hurt than good, to 30 pieces of the a-
bove lengths; and make a cold lye of it,
by stirring and pouring water off the
lime, until all be dissolved, but the dross,
which is thrown away: then I add a little
soap, which makes the lye have the
nearest resemblance to milk that breaks
in boiling, of any thing I can think of:
for this soap blunts the hotness of the
lime. Then I take the cloth, and dip it
in the lime-lye, and that moment out a-
gain, and lay it on a dreeper until it be
bucked; then put it on the field, watering
it carefully; for if allowed to dry, it is
much

“ much damaged. This is done always in
 “ the morning ; as it cannot be done at
 “ night, in regard of the hot quality of the
 “ lime, which soon heats the cloth, and ten-
 “ ders it. If a hot sunshine follows, it has
 “ great effect ; for lime is just like all other
 “ materials for bleaching, that have more or
 “ less effect according as the weather is
 “ good or bad. I take it up the second
 “ day after bucking, and give it a little mill-
 “ ing, or hand-bleaching, or bittling, com-
 “ monly called *knocking* ; and lay it on the
 “ field again, watering it carefully as before.
 “ The effect is more visible the second than
 “ the first day. As all cloth when limed
 “ should have a great deal of work, other-
 “ wise more than half the effect is lost ; and
 “ not only that, but a great deal of labour
 “ and pains is requisite to take the lime out
 “ of the cloth again ; it must never be ex-
 “ posed on the *Sabbath* day, but carefully
 “ kept wet always while used in this way.
 “ Thus bucking for three or four times at
 “ most, is sufficient for any cloth, except
 “ that made of flax pulled either over-green,
 “ or which grows in a drougthy season, or
 “ perhaps

“ perhaps not so well heckled as it should be.
 “ This sort occasions great trouble and ex-
 “ pence to the bleacher. But the most ef-
 “ fectual and expeditious way I ever found
 “ for this kind, was, after boiling, to take
 “ a little of the warm lye, and mix a very
 “ small quantity of lime with it, and draw
 “ the cloth through that as hot as possible,
 “ and put it on the field directly, watering
 “ it carefully. This will clean it of the
 “ sprat surprisngly. Then I boil it with
 “ pearl ashes, and give it the last boil with
 “ soap.

“ THERE are innumerable mistakes in
 “ the use of lime committed by the vulgar,
 “ who are ignorant of its quality and effects.
 “ They know only this in general, that it
 “ is a thing which whitens cloth cheap,
 “ and is easy purchased; therefore they
 “ will use it. Some of them begin whiten-
 “ ing of their cloth with it, which I have
 “ already observed to be wrong, and given
 “ reasons for it, and continue it until the
 “ cloth is bleached; give it a boil or
 “ two at most, and then wash it up while
 “ the

“ the gross body of the lime is in the sub-
 “ stance of the cloth. This makes limed
 “ cloth easily distinguishable from unlimed ;
 “ as the former has a yellowish colour, and
 “ is full of a powder. Besides, as lime is
 “ of a very hot corroding nature, it must
 “ by degrees weaken the cloth. The bad
 “ effects of this substance do not end here.
 “ When the cloth is put on board, it con-
 “ tracts a dampness, which not only makes
 “ it yellow, and lose any thing of colour it
 “ has, but directly rots it. And although it
 “ should escape this, which it is possible it
 “ may, by a quick and speedy passage ; yet
 “ whenever it is put in any warehouse, it
 “ will meet with moisture there, especially
 “ if the winter-season should come on be-
 “ fore it is disposed, or made use of. These
 “ I take to be the principal reasons for so
 “ much complaint in bleaching with this
 “ material.”

THE whole art and safety in using the
 lime, according to this method, depends on
 the junction of the alkaline salts, during the
 bucking, to the particles of lime which
 were

were on the surface of the cloth. I should rather prefer their junction in the lye; as it may happen, that some parts of the cloth which have received the particles of lime, may not, for several accidents, receive those of the salts. That lime is not so proper in the first buckings, I very much doubt; as it is used in the foreign materials, according to the *Dutch* method, from the beginning. The breaking of the lime-water, when soap is mixed with it, is owing to the former being a hard water. This will be fully explained in the following section. It is not surprising that cloth bleached with lime alone should, though well dried, contract moisture, when we consider the strong attraction or affinity that there is betwixt lime and water.

I have been assured, that, in whitening yarn at *Manchester*, there is always a fourth part of lime added to the salts. I have discovered that it is used in the same way in this country. I know no objection to it, but that of its being against law.

Sect. I. ON BLEACHING. 217

Cor. 9. Lime-water, with a grain and a half of pearl ashes added to each ounce, hurts cloth but very little, and whitens very much. This is a mighty cheap composition, and therefore deserves the consideration of bleachers.

Cor. 10. The effects of these different bleaching materials on cloth are increased by heat. They operate stronger when kept in a heat nearly equal to that of the human body, than in the heat of our atmosphere in the summer: they operate still more strongly in the heat of boiling water, provided that heat is brought on by degrees. This is easily accounted for, when we consider, that the intestine motion of fluids is augmented by heat, whereby the impetus or momentum of those solvents become stronger, and consequently their effects sooner produced.

Cor. 11. Those materials that whiten soonest, seem to extract most out of cloth, and to weaken it most speedily; while those that whiten slowly, extract but little from
E e cloth,

cloth, and therefore do not weaken it. This general rule admits, however, of many exceptions.

Cor. 12. Great plenty of air arises during the operation of these menstruums on cloth. This shows, that there is some substance, which contains plenty of fixed air, dissolved, and separated from the cloth. Dr *Hales* observed great plenty of air-bubbles arising from calculi, while they were dissolving in soap-lyes.

Cor. 13. Acid and alkaline salts lose, in the same proportion, as they operate on cloth, their acid and alkaline taste, and appear to be sheathed or destroyed by a junction with the substance they extract.

Cor. 14. *Muscovy* ashes, having the same proportion of pearl ashes added to them as are used in the bleachfield, seem to lose their corroding quality in a great measure. The common practice of the bleachfield was sufficient to have taught this. The
linen-

Sect. I. ON BLEACHING. 219

linen-bag, through which the lye is strained, will serve for two years.

Cor. 15. Pure sea salt does not whiten cloth, but opens, thins, and weakens it. Hence kelp ashes, which contain about a fourth part of sea salt, must have the same effect. This is one reason, among others, why the *Irish* cloth is so thin and weak, as the kelp ashes are generally used by them in the first buckings. Their most skilful bleachers have laid it entirely aside, and use only the *Cashub* ashes. How the kelp ashes may be freed from the sea salt, I have considered in a former section.

Cor. 16. Washing with warm water and soap, and rubbing with the hands, are not capable of taking out all the acid or alkaline salts out of cloth that has been steeped in them. It is only to be done by alkaline and acid salts.

Cor. 17. Cloth boiled in old lye gains considerably in weight, instead of losing. Hence it would appear, that old lye is not

so proper for steeping, the design of which is to take out the dirt and dressing.

Cor. 18. Cloth regularly watered, and exposed to the influence of the air, loses considerably of its weight, even though it has been well washed and rubbed in soap and water. This shows, that the air, sun, and winds exhale something, that washing and rubbing cannot take out; and therefore that the latter can never supply the place of the former, and be attended with the same advantage.

Cor. 19. Cloth, during the process of putrefaction, turns blackish, throws off a great deal of black matter, and is weakened. These effects must depend on the quickness and degree of putrefaction. Hence it is long before the putrefaction of plain water weakens cloth. Hence great care must be taken, that no corrupted butter milk should be used in the bleachfield: A circumstance too little attended to. The same caution must be observed with regard to the time at which the souring process ends;

ends; for immediately to that succeeds the process of putrefaction.

Cor. 20. *Castile* soap appears to be a very weak bleaching material, and not to correct the corroding quality of *Muscovy* ashes or lime. It may however be attended with other advantages. I find that it keeps the cloth soft. Mr *Chrystie* says, that cloth, when soaped, keeps longer moist, and is easier cleaned from the stain of a dirty foot.

Cor. 21. Butter milk seems to have some gentle tendency to whiten cloth when yet brown. To cloth already white it would seem to add somewhat, and to recover, in some degree, its strength when impaired. By its fermentation the acid particles are disengaged, and uniting with the absorbent earth left in the cloth, render it soluble in water.

Quær. What effect will the juice of onions, leeks, or celery, have on cloth? They appear by experiment to have a gentle power in dissolving the stone.

Quær.

Quer. What effect will shell marl have on cloth?

THESE are all the experiments which I have made with regard to the effects of different bodies on unbleached cloth. Though few, they are sufficient, I hope, to settle the genuine effects of these bodies; to teach the bleacher what he is to chuse, and what to reject; how to balance safety and expedition, that his method may not become too expensive by studying only the former, or too dangerous by pursuing too eagerly the latter; and what is of greatest importance, by what steps the art is to be advanced. But this is not all. The use of these experiments may be rendered far more extensive. They teach the varied effects of various bodies, when applied to one another. They increase the science of nature, and lead us to its true philosophy. They heighten our admiration of its great author.

S E C T.

S E C T. II.

The cause and effects of hard water, and the methods of softening it.

THERE is no subject so often mentioned, and so little understood, as the cause of hardness in water : there is no subject of greater importance to the bleacher, or indeed to general use ; there is no subject, of equal moment, that has been less considered, in an experimental view, than the present ; for it lies, so far as I know, yet untouched. These considerations induce me to undertake it. We have hitherto been contented with a showy theory, how well founded, the following experiments will make appear, that sea salt, if not the only, was the most general cause of hardness in water. Even experiments helped to corroborate this opinion ; but experiments made with materials not well understood ; and therefore deceitful.

THE regular method of proceeding in this inquiry,

inquiry, seems this, To try whether we can soften hard water, by mixing different materials with it, or treating it in different ways; than to endeavour to harden soft water; and, lastly, from these experiments, and from others, to discover the true cause of the hardness in water.

It is necessary to define our terms. Water is generally understood to be hard, when soap, agitated in it with the hand, does not raise a froth or lather on the surface, nor dissolves equally through the water, but curdles, or separates into a thicker and thinner part; the former of which mounts to the surface, and there remains like a white oil, while the water continues transparent below. Hard water has other distinguishing marks; such as, not softening pease that are boiled in it; boiling fish better than soft water; extracting less strength out of malt in brewing; preserving the colour of greens boiled in it, better than soft water; and not taking the dirt out of foul linen so well when washed in it. These I think too vague and undetermined to be taken as standards for experiment.

experiment. The curdling of soap I shall then make my fixed point; on one side of which the soft waters lie, and on the other the hard. We shall call this the *curdling point*. This standard of hard and soft water is more certain than any of those commonly known; and has the advantage of being understood by every body. Our experiments will furnish us with a substance which shows the hardness of water long before soap can discover it; but not more certainly. We shall make the proper use of it afterwards; and follow, at present, the common standard of hard and soft waters. The hard water used in the following experiments, was taken in *July* from a well when it was low.

THE water which flows from the pipes dissolves soap easily and equally; but this water curdles it directly, and in half a minute the soap rises to the surface. In the former water many air-bubbles arise on the surface, during the agitation, and remain for a long time; but in the latter few are to be seen, and those immediately disappear. In the former *ol. tart. p. d.* makes no lactescency or milky colour;

F f

but

but it does in the latter. The soft water was specifically lighter than the hard water; for a piece of glass, that weighed in the former 3 dr. $18\frac{3}{4}$ gr. weighed in the latter half a grain less. To discover how far beyond the curdling point this hard water was, the following trial was made.

Exp. 84. Three parts of soft water and one of hard were mixed, and dissolved soap equally; so did two of the former to one of the latter. Equal parts of the soft and hard broke the soap; but I observed through the glass, that the solution was not quite so equal as the former. When the soap was mixed with two parts hard to one of soft, the soap arose; but seemed to separate with some difficulty: and the line of separation was not so distinct as in the following mixtures, nor the liquor below so clear. When it had stood half an hour, I mixed the whole together with a spoon, and it never afterwards separated. This last, then, I must look on as the first degree of hard water, and the mixture before it as the last degree of soft water. When three parts of hard
were

Sect. II. ON BLEACHING. 227

were added to one of soft, the curdling was quick, the line of separation distinct, and when mixed together, it again separated. This shows how far beyond the curdling point lies the hard water, which I used in these experiments.

FIRE is generally thought to soften hard water. One is naturally led to think so, as boiled water has a softer taste than cold water, when made into punch. To ascertain this point,

Exp. 85. I tried the hard water when it was so warm that I could just hold my hand in it; but the soap curdled as fast as before. After it had boiled a quarter of an hour, it was still the same. There was no alteration, as to this quality, after it had cooled for two hours. Eight *English* pints were boiled into one; it seemed then much harder than before. Boiling, then, appears rather to harden this water, than soften it.

It is the general opinion, that all waters are softened by putrefaction, and that stag-

nation and exposition to heat are attended with a degree of it. That I might bring this opinion to the test of fact,

Exp. 86. July 1. I exposed 4 *English* pints of this hard water in an earthen vessel near a constant kitchen-fire. *July 14.* Still sweet and hard. *24.* Still the same, and continued so till it was thrown out, *Nov. 11.* as incapable of corruption. At that time it was reduced to the half; and, instead of being softer, was twice as hard as at first; for it required twice its quantity of soft water to make it break soap.

WHEN I saw that this water had no appearance of becoming putrid, I put, *July 24.* into the same quantity of the same water, in another pot, a large handful of dung to hasten its putrefaction. The water had a gentle corrupted smell for two or three days; but after that, became sweet, and continued so, as likewise hard, on the 11th of *November*, when it was thrown out.

THAT

THAT I might overcome this antiseptic quality in hard water,

Exp. 87. Nov. 11. Into a quantity of this water I put some flesh, and into the same quantity I put the same quantity of fish. *Dec. 10.* Both waters were very putrid. The water in which the fish had been, was now soft; that with the flesh was still hard, though a small degree of heat made it break the soap too. By another experiment I found, that hard water, putrified by the assistance of flesh, became entirely soft. Hence we learn, that putrefaction softens hard water; and every tendency towards that process must have a proportionate degree of that effect. But hard waters appear to resist that change very powerfully.

It is generally thought, that hard water filtered through sand becomes soft. I was of the same opinion *, and had not trusted to theory alone for it. But being professedly

* Vid. Dunse Spaw, section on water.

engaged in this pursuit, and having made the experiment more exactly, and carried it farther than what I had done before, I find that this effect of sand is limited.

Exp. 88. A quantity of sea sand was well washed with soft water, each parcel three times, and then put into two casks that were set above one another. There was a hole in the centre of the bottom of the upper cask, by which the water was to pass into the lower; and a hole in the under part of the latter, by which the water was to issue through a pen. When the sand was wet with water, I observed it decreased considerably in its volume. This remarkable property of sand, which arises from a closer disposition of its particles by the water as it flows in, is wisely designed, by the author of nature, to answer several valuable ends. That I might wash out all the salts or soluble parts from the sand, soft water was filtered through it. The water came off hard for two days; but after that became soft. The hard water was then passed through the sand, and it came off entirely soft; nay
more

more so than the town-well water; as it seemed to dissolve soap better, when equal parts of it and hard water were mixed, than the town-well water had done in the same proportion. It appeared softer from the following trial. Three parts of the filtered hard water were mixed with one part hard water; the town-well water was mixed in the same proportion. *Ol. tart. p. d.* produced a lactescency in the latter, but not in the former: but when there were two parts of hard water to three of filtered, a lactescency just began to appear. But how cautious ought we to be in drawing general conclusions from the apparent success of an experiment! The water, running through a quill in a constant stream, continued soft for twenty-four hours; but after that it turned hard, and remained so.

THIS is easily accounted for. The substance, whatever it is, which makes water hard, finds great difficulty in passing through the interstices of the sand, but is not altogether stopped. Hence, by degrees, it is washed down by the water, and lies ready to

to impregnate the soft water which is issuing through the quill, while its place is supplied by that immediately above it; and so on in a continual succession. Thus the water must after a certain time become hard. From this experiment we may conclude, that soft springs at least are not supplied by the sea, as sea-water is hard.

THIS method of filtration may still be very proper to free impure waters of the filth they contain, or of their earthy and oleaginous particles, and clarify them. The water before it was filtered, was not only hard, but had a bad taste. Its taste after filtration was quite altered: it was nauseous before, but had a saline sweetness after.

I have heard, that great quantities of chalk thrown into wells of hard water made it soft. With this view I tried the following experiment.

Exp. 89. Powder of chalk, mixed with hard water, did not soften it. When boiled for a quarter of an hour in hard water,
and

Sect. II. ON BLEACHING. 233

and allowed to subside, the clear liquor was no softer than before. It does not therefore soften water, by any change that it makes on the water from an addition of its substance: but if it has that effect, it must act as a filter. This appears to be its method of acting: for hard water filtered through a height of chalk of two inches, came off so soft, that it broke soap; but *ol. tart. p. d.* produced a lactescency, in three parts of it mixed with one part hard water. The water filtered through the chalk so slowly, that I should be afraid of its not allowing the water to pass in any quantity, if the spring be in the bottom of the well. This was the case, as I am told, in a well where this experiment had been tried; for, afterwards, in dry weather it was always so low, that they could get no water out of it.

Exp. 90. Some hard water was clarified, by having the white of an egg beat up with it, and afterwards boiled. The soap broke pretty well at first in it; but, on standing

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some seconds, it curdled, and rose to the surface.

LIME was tried to soften hard water, and not without some hopes of success: for as it is thought a great corrector of the muriatic acrimony in the blood, it might have the same effect on the muriatic salts; the supposed cause of the hardness of water.

Exp. 91. Lime was mixed with hard water, but it was not softened by being made into lime-water. The same lime-water stood till the calcarious particles were all evaporated, but still the water preserved its natural hardness. We shall see presently that the real effect of lime is very different from the imagined one.

Exp. 92. It is generally thought, that fern softens water; and it is often used with that design: but infusing some of that vegetable in warm hard water, and letting it stand all night, I could not discover any such effect. The salts in it, though they do not soften the water, may perhaps quicken the effect

Sect. II. ON BLEACHING. 235

of water, when it is to operate as a menstruum, to loosen the oils of vegetables: for it is in the steeping of lint that fern is used.

LET us try what experiments made on no previous theory will produce.

Exp. 93. The extract of bark, of gentian, and of centaury, appeared, at my first trial, to have a power of softening hard water; but, on repeating the experiment, I found, that the dark colour of the solutions, or the mixture of some alkaline salts with these extracts, which sometimes happens, had misled me. Nor did I succeed better in softening hard water with the extract of wormwood, of black hellebore, of chamemile, or of logwood; with rhubarb, Bohea tea, lintseed, oak bark, gum Arabic, or gum ammoniac.

Exp. 94. A solution was made of 2 scrup. of blue pearl ashes in 2 oz. of soft water. Sixty drops of this solution, mixed with a spoonful of hard water, dissolved soap without curdling. A hundred drops of a solution,

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tion, that contained just 5 gr. of blue pearl ashes, made four spoonfuls of hard water soft; but the soap curdled on the addition of another spoonful. We have then found a softener of hard water where it was not expected. This experiment led me to try the following.

Exp. 95. Twenty drops of the spirit of harts-horn softened two spoonfuls of hard water. The same number of drops, mixed with the same quantity of hard water, and allowed to stand for two or three days till the smell of the spirit was gone, broke soap as well as with the recent addition. That I might find out the precise quantity of dry volatile salt, I dissolved 2 gr. in half a spoonful of hard water, which broke soap well; but when I added another half-spoonful, it was with some difficulty that it broke soap: but after it had done it, there was no separation. Thus we have found two substances, the fixed and volatile salts, which have a remarkable effect in softening hard waters. How far these may be applied with safety

safety to the common uses of life, we shall afterwards consider.

LET us next endeavour to discover what substances make water hard. I could not procure distilled or rain water in quantity enough to serve me in all the following experiments; but the most important were performed with the latter. We shall begin with the mineral substances.

Exp. 96. A large key was infused in soft water for a day: it made the water yellow, and gave it a strong chalybeate taste, but did not harden it. Neither did a red-hot iron quenched several times in soft water. Copper infused in soft water for two days, gave it a mineral taste; but did not change it into hard water.

SEA salt is commonly thought, if not the only, at least the most general cause of the hardness in water. It was natural to think so, when we found, that common sea salt curdled soap dissolved in water, and considered how general an ingredient it is in all waters.

waters. But the following experiments will show us, that this is not the effect of sea salt, but of the impurities mixed with it. The sea salt, which I used, is a particular kind that is only made on *Sunday*; and therefore called *Sunday-salt*, or great salt, from the largeness of its grains. It crystallises at a time when the fire is low, and the sea water not altogether evaporated, as it is in the common way of making salt. It contains less of the bittern than the common sea salt, and has therefore a particular sweetness. It is the most proper for the table and for experiments.

Exp. 97. A grain of pure sea salt was dissolved in 4 spoonfuls of rain-water. This solution dissolved soap well, and did not turn lactescent with *ol. tart. p. d.* Some drops of a solution of quicksilver in *aq. fortis* made a great lactescency in it; this lactescency was just perceptible when the solution of the sea salt was diluted with sixteen times its quantity of water. This solution of quicksilver, then, does not discover hard waters; it only discovers sea salt in wa-

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ter ; and that when in a very small proportion, 1 gr. in 3 *English* pints of water.

Exp. 98. A spoonful of rain-water, with 5 gr. of pure sea salt dissolved in it, continued soft. With 6 gr. there appeared a little curdling, but a little more agitation dissolved the soap. This curdling seems to be owing to some remainder of the bittern ; for 2 gr. of common sea salt made water as hard as these 6 gr. had done. The bittern has this quality so strong, that a fourth part of a grain of the bittern salt hardens a spoonful of rain-water. The spirit of sea salt saturated with an alkaline salt, does not harden water. The proof still becomes stronger, when a small lactescency appears on dropping *ol. tart. p. d.* into a solution of 5 gr. of pure sea salt in a spoonful of rain-water. From these facts it appears, that pure sea salt has no hardening quality, and that the bittern has it in a very strong degree. The hardness of waters can never be owing to the former salt, as the taste can discover a smaller admixture of it than what would be necessary

necessary to have that effect, if it ever has any such.

THUS pure and impure sea salts appear, by experiment, to have very different effects on bodies. I am afraid this has not been sufficiently attended to; and the effects of the bittern have often, unjustly, been attributed to sea salt. I have discovered, since I made the preceding experiment, that *Lemery* has long ago made the proper distinction betwixt these salts *.

THE common *Epsom* salt, sold in the shops, is the bittern or second kind of salt in sea water.

Exp. 99. Five grains of *Epsom* salt hardened 2 spoonfuls of soft water so much, that it required to be diluted in 16 spoonfuls, before it began to break soap. A great lactescency happened betwixt this solution and *ol. tart. p. d.*

Exp. 100. Alum renders soft water very

* *Cours de chymie, p. 307.*

hard;

Sect. II. ON BLEACHING. 241

hard ; so that 5 gr. required 20 spoonfuls of soft water before it would break soap. *Ol. tart. p. d.* made a lactescency.

Exp. 101. Salt of steel hardens water. I was obliged to dilute 10 gr. in 45 spoonfuls of soft water to make it break soap. Every one knows, that alkaline salts render a solution of this salt turbid and green.

Exp. 102. Blue vitriol or salt of copper hardens water so much, that 5 gr. required to be diluted in 35 spoonfuls of soft water to make it break soap. Alkaline salts turn a solution of this turbid and blue.

Exp. 103. Vitriolated tartar got from the apothecary's shop hardened water ; but finding that it had a strong acid taste, I made some, by dropping 40 drops of spirit of vitriol into a solution of salt of tartar. When the saturation was fully completed, I put the whole into two spoonfuls of soft water, and it dissolved soap very well. No lactescency.

Exp. 104. Five grains of the sugar of lead hardened water. When diluted in 24 spoonfuls, it began to dissolve soap. The alkaline solution made a lactescency in it.

Exp. 105. Crude ammoniac salt, borax, sal prunel, sal polychrest, gum ammoniac, chamemile flowers, oak bark, Peruvian bark, did not harden water. Nor did oil of tartar produce a lactescency in their solutions.

Exp. 106. Five grains of cream of tartar hardened soft water; but when diluted in six spoonfuls, it dissolved soap. No lactescency.

Exp. 107. Five grains of salt of amber made water so hard, that I was obliged to dilute it with 50 spoonfuls before it would break soap. No lactescency.

Exp. 108. Twelve drops of spirit of vitriol required eight spoonfuls before it would dissolve soap. One drop of oil of vitriol required to be diluted in six spoonfuls, the same

Sect. II. ON BLEACHING. 243

same quantity of spirit of sea salt in five spoonfuls, the same of nitre in three spoonfuls of soft water, before soap could be equally dissolved. A tea-spoonful of vinegar required eight large spoonfuls of soft water to make it break soap. The alkaline solution raises an effervescence, though it does not make a lactescency with these acids.

Exp. 109. Some powder of chalk was well mixed with cold soft water: it was poured off after the chalk settled, and dissolved soap. Soft water boiled with chalk for half an hour, was not hardened by it. Some clay wrought for some time in water, and allowed to subside, did not harden it. Lime renders water remarkably hard.

Exp. 110. Lime-water that was made with soft water, and had stood for three or four days over a great quantity of lime, which had before afforded some pints of lime-water, curdled soap at once, and became milky with the alkaline solution. One spoonful of this lime-water required six spoonfuls of soft water before it broke soap.

Ten ounces of lime-water was boiled into two, but it dissolved soap no better than before. The same lime-water, when it had become vapid with standing, broke soap as well as soft water. The hardness of lime-water appears plainly to be owing to the soluble parts of the lime; and the more water contains of these, it must be the harder. We cannot know from this the real quantity of these particles contained in the water; but we may know the proportionate quantity; and of course the comparative strength of different lime-waters. Let us, then, try to determine, by this test, an interesting question, Whether double or triple lime-water is stronger than single?

Exp. 111. I made some lime-water; in half an hour I poured most of that single lime-water upon fresh lime; about the same time after I poured most of that double lime-water upon fresh quick-lime; and so made a triple lime-water. When they had all stood about two hours, a spoonful of the single lime-water required to be diluted with 9 spoonfuls of soft water, before it would

would break soap ; the double required 12, and the triple 15. The times and force of agitation were, as near as I could make them, the same. I poured the triple lime-water again upon quick-lime. The other lime-waters were poured from the lime into open glasses. An hour and an half afterwards the single lime-water required 9 spoonfuls, the double 11, the triple 13, and the quadruple 17. This last experiment was made at twelve at night. Next morning the whole four lime-waters, having stood all night in open glasses, required but 9 spoonfuls, although the quadruple lime-water had stood over its lime all the night. This experiment agrees exactly with what I had formerly discovered by weighing their specific gravities. A piece of glass weighed 2 dr. 23 gr. in town-well water ; in single stone-lime water it lost a grain, and in triple a quarter of a grain more. This showed, the specific gravity of the triple lime-water was greater than that of the single, by a fourth of the difference betwixt the last and plain water. The lime-waters in this last experiment had stood for
two

two hours, till they were entirely clear,

I repeated the former experiment again, and I strained the waters, after they had stood an hour, through brown paper. The single lime-water required 8 spoonfuls of soft water before it broke soap, the double 9, and the triple 11. I was resolved to see how far it would go, and made a quadruple; but, finding it took no more than the last, I desisted.

THAT I might discover how long these different lime-waters would preserve a difference in strength, if kept in close bottles,

Exp. 112. I made single, double, and triple lime-waters, stirred them frequently for four hours, and then strained them. The single required 15 spoonfuls of soft water, the double 18, and the triple 20, before they broke soap. They were bottled, corked, and waxed over. After they had stood 10 days, they required the same quantity as before to soften them. When kept some days longer, the single was still of
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the same strength, but the triple required only 18 spoonfuls of soft water.

As it may be objected to these experiments, That the water had not stood a sufficient time over the lime, nor had they been frequently mixed together,

Exp. 113. I made two different quantities of lime-waters, with two parcels of the same quick-lime. I tried one of the lime-waters in the above-mentioned way, after it had stood without stirring for two hours. The other stood over the lime twenty-four hours, and was frequently stirred. They were equally hard, and therefore equally strong. Lime-water then made with un-slaked lime, need stand no longer than it is clear.

THE conclusion, then, from these experiments, is, that lime-waters made with different lime, differ very much from one another; that double lime-water is stronger than single, and triple than double; and that they retain their different strengths, if kept

kept from the influence of the external air; but if exposed to it, in open vessels, in a few hours become of equal strength.

To try what effect alkaline salts had as to the softening of lime-water,

Exp. 114. I poured on quick-lime some water, in which the fourth part, in proportion to the lime, of blue pearl ashes had been dissolved. The water had a sharp pungent taste, and seemed to be about the hardness of the hard water, which, though hard, is much softer than lime-water. The softening power of the alkaline salts, appears yet better from the following experiment. One ounce of potashes dissolved in two gills of water, and poured on an ounce of quick-lime, produced a very caustic liquor, which broke soap, but not speedily. Lime-water is softened by an addition of alkaline salts. From this experiment we may see the reason, why the soap mixed with the lye, which is a composition of lime and alkaline salts, is not curdled.

Sect. II. ON BLEACHING. 249

A table of the comparative power of bodies with regard to softening and hardening of water.

Comparative softening powers.

Filtration through sand softens in proportion to the length of its course.

Putrefaction softens in proportion to its degree.

Volatile salt of hartshorn	——	1
Fixed alkaline salts, though not of the strongest kind	—— ———	2

Comparative hardening powers.

Epsom salt	—— ———	3
Alum	—— ———	4
Salt of steel	—— ———	4½
Blue vitriol	—— ———	7
Sugar of lead	—— ———	5
Cream of tartar	—— ———	1½
Salt of amber	—— ———	10
Oil of vitriol	—— ———	18
Spirit of sea salt	—— ———	15
Spirit of nitre	—— ———	9
The soluble part of lime	——	45

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IN computing the hardening power of these acid spirits, I have allowed 3 drops to be equal to a grain ; which may serve very well in a general way of computation. But when we consider, that there is but a part of these spirits real acid, and that those which I used had been negligently kept, we shall see reason for attributing a very strong hardening power to the real acid salts of these liquors. By the trials which I have made, there appears to be but 1 gr. of the soluble part of lime in 5 oz. of lime-water, which I reckon equal to 8 spoonfuls ; and one spoonful was found to require 6 spoonfuls of soft water to make it break soap.

IT must be observed, that all these artificial hard waters, except those made so with acids, were rendered turbid or lactescent with alkaline salts. This will be found a general rule, That where-ever soap is curdled, alkaline salts produce a change in the colour and purity of the water ; because both effects depend on the same cause. Hence arises a new standard to help us to judge of the degree of hardness in waters. Let

Sect. II. ON BLEACHING. 251

us inquire at what time this change of colour arises; it may, perhaps, discover a less degree of hardness in water than soap does.

Exp. 115. A mixture was made of equal parts of hard and soft water. This we found before not capable of curdling soap, and, therefore, called it the last degree of soft water. This soft water, on dropping some of the solution of pearl ashes into it, turned as white as the hard water did with the same solution. When two parts of soft water and one of hard were mixed, a lactescency arose with the solution, but weaker than in the last. When three parts of soft were mixed with one of hard, a very discernible alteration of colour still happened. Thus we see, alkaline salts discover a much less degree of hardness in water, than what soap does. Let us therefore call this degree of hardness in waters, whereby they are made to change their colour with alkaline salts, the *lactescent point*.

WE are now on a better footing than what we were when we set out. We have

gained two fixed points in hard waters, that will allow of comparison. We may now divide all waters, with regard to this quality of hardness, into three sorts. The first are those which neither change with alkaline salts, nor curdle soap; the second, those which lose their transparency with these salts, but in which soap is not curdled; the third sort are those where both effects happen. The first class are the softest of all waters, and the fittest for most uses in life; the second class, at least the first degrees of that class, may do tolerably well in the common household-affairs, though not in the bleachfield; but the third sort I condemn as hurtful, and improper in almost all cases. The water which issues from the pipes of *Edinburgh* wells, is in the first class: for it not only breaks soap well, and retains its transparency when salt of tartar is mixed with it; but likewise shows no lactescency, when a solution of quicksilver in aqua fortis is dropped in it. By this last we discover, that if it contains any sea salt, it must be in a less proportion than one grain to three

English

Sect. II. ON BLEACHING. 253

English pints; too inconsiderable a quantity to be taken notice of.

THE foregoing observation leads us likewise to another very material conclusion; which is, that the curdling of the soap is brought about by the alkaline salts, and not the oil: which two bodies, with a little lime and sea salt, make up the composition of hard soap. The sea salt has not that effect, as we proved before; and the lime is in such a small proportion, and mixed with alkaline salts, which we just now found softened it, that it cannot be the cause of the curdling of soap. We have found, that neither natural nor artificial waters ever curdle soap, without having their composition altered, or visibly affected by alkaline salts: it therefore follows, that the alkaline part of the soap is the part on which these hard waters work. Accounting for the lactescency with salt of tartar, is accounting then for the operation of soap. It is no wonder that hard waters produce their effect somewhat later on soap, as it is defended by the oil from their operation longer than

than the naked salts. As soap is a more compounded body than the salts, the circumstances resulting from a mixture of hard water with each must be very different.

WE have discovered, in these experiments, three different causes of hard water; quick-lime, acids, and neutral salts. This property in lime shall be examined by itself. Acid salts, such as the oil and spirit of vitriol, the spirit of sea salt, and that of nitre, vinegar, Cream of tartar, and salt of amber, hardened water remarkably. Why they should do so, is easily explained. The alkaline salts having a stronger tendency to the acid than to oil, quit the latter, and adhere to the former. Hence the artificial composition of soap is destroyed, and the oily part, separated from the alkaline, floats like clouds, and at last, by its specific lightness, rises to the surface. The stronger the acid is, every thing else equal, the harder must it make the water. Hence the mineral acids, considering the great proportion of real acid in them, have the strongest effects: but these can seldom or never impregnate

pregnate natural waters, because absorbent particles are found almost every where; which would directly join the acids, and reduce them to neutral salts. In fact no acid water has yet been discovered. This leads us to consider these neutral salts as the general cause of hardness in water.

WHEN I look back on these experiments, I cannot but observe one remarkable fact; which is, that none of the more perfect neutral salts, compounded of an acid and alkaline base, render water hard; but that all the imperfect salts, compounded of an acid and absorbent earth, or a metal, have this effect on water. *Epsom* and alum salts have an absorbent earth for a base; salt of steel, sugar of lead, and salt of copper, a metallic one. It is a fact known to all chymists, that when alkaline salts are poured on a solution of the imperfect salts, the acid quits the absorbent earth or metal, and joins the salts; because the power of attraction betwixt the acid and salts is stronger than betwixt the acid and earth or metal. But when these alkaline salts are added to the solution

lution of the more perfect salts, no change can happen; because the alkaline salts, to which they are already united, attract the acid as strongly as those that are now added. It is the same thing then with respect to the alkaline salts, whether the acid is or is not joined to a metal or absorbent earth, since it so easily leaves them. But the effects which follow will be different: for, in the former case, the liquor must lose its transparency, at least for some time, on account of the deserted particles which float in the liquor; but in the latter no such effect can happen, and the liquor must continue limpid.

HENCE arises already a great presumption, that these imperfect salts are the common cause of the hardness in waters, since the appearances in both cases correspond so exactly: for a curdling of soap, a lactescency, and precipitation, are observed in both natural and artificial hard waters. But it must seldom happen, that the hardness of waters is owing to a neutral salt, composed of an acid and a metallic base; considering

Sect. II. ON BLEACHING. 257

ing how much oftener the acid must be joined to an absorbent earth. The former does sometimes happen: for the *Hartfield* water is very hard; and experiments show, that it contains a salt of steel, and no other. When this is the case, the water becomes a mineral water, and will soon discover itself by its mineral effects. In all hard waters, then, excepting the mineral, we may presume, that there is an imperfect neutral salt.

THIS cause of hardness in waters accounts for the power which alkaline fixed and volatile salts have of softening these hard waters. These two bodies unite themselves with the acid, and throw off the absorbent earth: the fixed salts constitute with the acid a perfect salt; which species of salts, as we already discovered, has no power of hardening water; and therefore the water becomes soft. The volatile alkaline uniting with the acid constitutes an ammoniacal salt, or one like it; which we found likewise not to harden water; and therefore the hard water becomes soft. The water is

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rendered by that change on the salts more healthful; which we were not sure of when the fact was first discovered.

LET us try how far experiment will support this theory of hard waters: for I can allow it to be as yet nothing but a theory, though a plausible one; since it arises only from a similitude of effects betwixt natural and artificial hard waters. If this theory be true, we shall be able to exhibit to the eye these hardening salts, or at least some part of them; by which we may discover, that the other part has been once present. Let us see what evaporation will give us.

Exp. 116. Four *English* pints of this hard water were evaporated to driness, and left 26 gr. of a brown powder, which had a pungent saline taste, and liquified in the air. This powder effervesced with both vegetable and mineral acids; but it effervesced likewise with a solution of alkaline salts. It must therefore be a composition of both acid and alkaline salts, or absorbent earths; the latter of which seem to prevail, as the powder

Sect. II. ON BLEACHING. 259

powder turned the syrup of violets green. Brown paper dipped in a solution of it, and dried, burnt like a nitrous match. Six grains and a half of the powder dissolved in a pint of soft water, made it so hard, that it would scarcely dissolve soap. In this residuum, then, we have discovered the hardening cause; but it appears, that about the half of it has been dispelled by the evaporation. It is probable, that this volatile part is an acid, as the residuum seems to partake most of a contrary nature.

LET us see whether we cannot make this acid more fixed and more visible, by joining it to an alkaline base.

Exp. 117. Into four and a half gills of hard water, was dropped *ol. tart. p. d.* as long as any lactescency was made by it. During the addition of the alkaline salt, I observed through the glass a very great intestine motion in the liquor: some air-bubbles, though but very few, arose; and the clouds dispersed themselves through the whole with a considerable motion. But no

such effect happened when I dropped the same solution into soft water. Here then is a plain and distinct intestine motion or effervescence. The liquor, having stood all night, appeared transparent in the morning, and the bottom of the glass was covered with a whitish powder. The water now broke soap. When the whole was shaken, it turned white; which shows the milky colour is owing to this powder. The liquor was strained through brown paper, and I had five grains and a half of white powder. To be sure that this precipitation did not ever happen in soft waters, and that it was no part of the alkaline salt, I dropped the same quantity of *ol. tart. p. d.* into the same quantity of soft water; but no precipitation followed. This powder, when mixed with soft water, did not harden it; when kept in a strong kitchen-fire for two hours, it was reduced to good quick-lime.

THAT I might discover the contents of the hard water, after the addition of alkaline salts,

Exp.

Sect. II. ON BLEACHING. 261

Exp. 118. Three chopins of hard water were treated in the same way, and evaporated to 2 oz. of a red liquor. The first salt that separated from the liquor weighed 15 gr. It turned syrup of violets green, and effervesced with spirit of vitriol; marks of its being alkaline. More alkaline salts had been added than what were necessary. The next crystallisation afforded me a scruple of a salt, which, though it seemed to be of an alkaline cast, approached much nearer to the neutral state than the former, gave strong marks of a nitrous salt, and afforded me great hopes from the next crystallisation. It succeeded accordingly. In a night's time I had half a drachm of fine white crystals, some of them an half-inch in length, and exactly like the regular crystals of nitre. They had a bitter cooling taste; when joined to oil of vitriol, emitted strong acid fumes, and corroded silver; when vinegar was poured in them, a few air-bubbles arose: but these seemed plainly to be owing to the alkaline liquor round them; for the crystals lay for some time, after the intestine motion ceased, undissolved at the
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the bottom of the glass : when brown paper was dipped in a solution of them, it burnt, and sparkled like the same dipped in a solution of saltpetre. These characteristical marks, with its effects of turning flesh red when boiled in the water, are sufficient to prove it to be a real saltpetre ; for these are the properties of that salt, and belong to no other. The liquor remaining was of a dark colour, and tasted like a solution of sea salt.

THE earth in this hard water we demonstrated before to be of the calcarious kind, and convertible into lime. We have at present demonstrated the acid of this hard water to be that of nitre. The chymists deny that such an acid exists in nature, and affirm, that it is made from the vitriolic and an inflammable principle conjoined : but here we have found it present, and have helped to volatilize it. *Hoffman* denies the existence of nitrous waters, and says, that an inflammable fossil nitre is no where to be found *. Here, indeed, the nitre was in

* De element. aq. mineral. &c. par. 39.

Sect. H. ON BLEACHING. 263

an imperfect state, but still inflammable. There is great probability, that a real nitre may sometimes exist in the bowels of the earth, since the alkaline base often appears in waters. The experiments performed on mineral waters at *Paris* before the Royal academy of sciences, demonstrate clearly the existence of a nitrous salt *.

SINCE this acid seems of so volatile a nature, let us try if hard water distilled gives any sign of containing an acid.

Exp. 119. I distilled some hard water. The distilled water showed no effervescence with alkaline salts, but turned the syrup of violets into a light red. Common soft water had no such effect. Here, then, we discover an acescent quality in the steams of hard water, that can rise only from an acid existing in that water; and as the water gives no marks of acidity, we must conclude, that, by adhering to an absorbent base, it is converted to a neutral salt.

* Vid, Du Clos.

THERE cannot be a stronger proof that waters owe their hardness to such a salt, than to show that similar artificial compositions have this effect. Such salts as these must be continually produced by nature; as an acid and different absorbent earths are almost every where to be found.

Exp. 120. Four grains of the earthy residuum of white pearl ashes were saturated with the spirit of vitriol, and half an ounce of water added. Two parts of this saline liquor added to three of the rain-water, would not break soap.

Exp. 121. The same quantity of chalk was managed the same way. Two parts of this to three of rain-water made the soap rise to the surface.

Exp. 122. Six drops of spirit of nitre, saturated with chalk, made soft water so hard, that it required 60 spoonfuls before it would break soap.

Exp. 123. The same quantity of spirit of
sea

Sect. II. ON BLEACHING. 265

sea salt saturated the same way, required 80 spoonfuls.

Exp. 124. The powder which was precipitated by *ol. tart. p. d.* from three *English* pints of hard water, being saturated with oil of vitriol, made the same quantity of soft water nearly as hard as what the former had been; for equal parts of this artificial hard water mixed with soft, dissolved soap, though with some difficulty. The quantity of acid added was 66 drops. There was a great part of this earthy substance, which the acid could not dissolve.

THESE different experiments seem to have clearly made out, that the hardness in this water is owing to an imperfect salt, compounded of the nitrous acid and an absorbent base. It is probable, that most waters, excepting the mineral, owe their hardness to the same cause; especially when we consider that it is observed of them all, that they give flesh boiled in them a red colour. I have examined many different hard waters in different parts of the country, and have always discovered the acid to be ni-

trous, but the base only absorbent, and never calcarious but in the foregoing. Thus we see the very ingenious Dr *Stephen Hales* has come near the true cause, when he says, “ That the hardness of many waters, and “ their curdling and coagulating of soap, may “ be, in a good measure, owing to the tar- “ tarine quality with which they are impreg- “ nated.” By the tartar of waters, the Doctor, I suppose, means that stony part which is deposited on the inside of vessels. This is, indeed, one part of the composition of these hardening particles: but this alone we found to have no such effect; it is to the acid, and these absorbent earthy particles, compounded into a neutral salt, that we have, by experiment, discovered this hardness to be owing.

HAVING now examined the effects of alkaline salts on natural hard waters, and, by that means, made a discovery of their nature, let us examine the effects of these salts on lime-water; for that, perhaps, may give us some light into the nature of lime.

Exp.

Sect. II. ON BLEACHING. 267

Exp. 125. Into 6 gills of lime-water, strained from the crusts, I poured a solution of alkaline salt, till no more lactescency appeared. The quantity of dry alkaline salt required, was 8 gr. During the addition of the solution, there appeared a great intestine motion, such as happened in the hard water; the milky clouds moved swiftly through the fluid; but I perceived no air-bubbles. It is not, however, in the appearance of air-bubbles, but in the intestine motion, that an effervescence consists. The lactescent mixture, having stood all night, was clear next morning, and had deposited a white powder. The whole being shaken together, was strained through brown paper, and left an impalpable powder, weighing 4 gr. when dried. The remaining liquor did not effervesce with acids; and when evaporated, left 11 gr. of a light brown powder.

THE former powder did not liquify in the air, nor dissolve in the mouth like a saline substance. It tasted as if a little sea salt had been mixed with it. It effervesced

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strongly

strongly with spirit of vitriol ; and emitted a sharp acrid smell, when oil of vitriol was mixed with it. Being calcined, and mixed with water, it afforded a good lime-water.

THE latter powder had a pungent saline taste, turned moist by keeping, was not altogether dissolvable in water, did not afford a lime-water before calcination, and effervesced strongly with vinegar. Three grains of the powder mixed with $1\frac{1}{2}$ oz. of water, made it turbid, and the powder fell directly to the bottom. Some of the water, when strained, effervesced with spirit of vitriol. This shows, that part of the powder is dissolvable. With the remaining unstrained liquor, spirit of vitriol made a strong effervescence ; there remained half a grain of powder that was undissolvable by the spirit. Some of the powder being calcined for two hours, I got an acrid pungent substance, which tasted exactly like a lye of salts and lime, and had the same taste when dissolved in water.

Exp. 126. I tried this experiment again,

to be assured of the facts. The same quantity of strained lime-water was used, and the same quantity of the same solution. The residuum left in the paper weighed 6 gr. and that got by evaporation from the liquor weighed 10 gr. The latter was now so caustic, that it blistered the tongue on touching it; was almost indissoluble in water; and had the taste of the caustic liquor drawn from lime and salts. The former, when calcined, tasted just like quick-lime; made a hissing noise when water was poured on it; and gave good lime-water.

It is difficult to account for these phenomena: we shall, however, make some attempt towards it, and carry, when it is possible, experiment along with us.

It is sufficiently made out by Dr *Alston's* accurate experiments, that quick-lime consists of a dissolvable and an undissolvable part. The former appears to be about the third part of the whole. The latter is reducible, by fire, into the former; and therefore we shall treat only of the dissolvable

vable part. There are many disputes concerning its nature. That it should be so, is not at all surprising, considering how late chymists were in examining this substance, and how few experiments have yet been tried with regard to it.

THE first dispute is, whether it ought to be called a salt or not? This seems only to concern words. If the definition of a salt had been first given, I imagine this dispute would soon have been determined. If a salt be a substance which has a pungent taste, and is dissolvable in water; and I know no other definition but this, that can suit all salts; surely the dissolvable part of lime has as good a title to be ranked in that class, as any other salt, as it imparts such a sensation to the palate, and is dissolvable in water. It is in the solubility itself, and not in the degree of it, that the nature of salts consists. That it, afterwards, changes into crusts, and becomes unsoluble, never can affect it in its former state; because it is then altered, and no more the same body, though reducible in part to it.

WHAT

Sect. II. ON BLEACHING. 271

WHAT is the nature of this soluble substance? is the next question. Monf. *Du Fay* has endeavoured, in two papers, to make out, that it is, or that it contains a neutral salt; for he never says, that he extracted all the salt from lime that could be got. He seems only to have got the most soluble parts of this substance, or, as Monf. *Malouin* thinks, the crusts, and to have mistaken them for a neutral salt. Monf. *Malouin* says, that the salt of lime is a true neutral salt, consisting of a vitriolic acid and a terrestrial base. This he proves, by telling us, that, on mixing an alkaline salt with lime-water, he got a tartar vitriolatus; on mixing, in the same way, the base of sea salt, he got Glauber's salt; and on adding an inflammable body, he got a sulphur.

By the preceding experiments, it appears, that no such salt as the tartar vitriolatus is formed from alkaline salts and lime-water; and therefore that gentleman must have been led astray by some foreign admixture in the lime he used. Perhaps when lime-stone is burnt with a coal very much impregnated

impregnated with sulphur, a small quantity of the vitriolic acid may adhere to it, and produce the effects mentioned by *Monf. Malouin*. *Monf. Mackay*, in a short but elegant treatise on chymistry, has shown, by some ingenious experiments, that no such acid can exist in lime; for he found, that an addition of this acid to different calcareous stones, changed their nature to the vitrescible. The same effect happened in *Exp. 22*. Lime in its nature is the very opposite of vitrescible bodies.

WHEN I first observed a lactescency in lime-water, and a subsequent precipitation of a powder, and considered, that I had only found this effect happen in imperfect neutral salts, I was very much inclined, from analogy, to believe, that lime contained such a neutral salt. The opinion was very natural. I knew of no method to procure this salt, by itself, but by dissolving it in water. There acids make no effervescence. This, however, could be no proof, that the salt dissolved in it, was neutral, when I found that a grain of alkaline salts dissolved

Sect. II. ON BLEACHING. 273

dissolved in $3\frac{1}{2}$ oz. of common water, made no effervescence with acids. I took the following method therefore to determine its nature.

Exp. 127. I skimmed off the subtilest and lightest parts of lime dissolved in water, as I had done in some former experiments. Part of this was boiled in water, till it did not taste of lime, nor made lime-water. These two, and some of the crusts taken from the same lime-water, were dried in an equal heat. Six grains of the effete lime required 26 drops of *spirit. sal. marin.* to saturate it; 6 gr. of the unboiled, 41 drops; and the same quantity of the crusts, 21 drops. I added 2 tea-spoonfuls of water to each powder, before the acid was dropped into it. The first was pale, and had a dark oozy sediment; but the second was yellow, and had no sediment. It was remarkable, that they all emitted strong acid steams during the act of fermentation. The conclusion then from this experiment is very plain, that, allowing 18 drops for the 4 gr. of the unsoluble part in the unboiled lime, which

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is the proportion that the boiled effete calx took, the 2 remaining soluble grains must have consumed 23 drops of the acid; a quantity twice and a half more than the un-soluble part required. The soluble part then is so far from being a neutral salt, that it becomes, by the action of the fire, betwixt two and three times more antacid than the un-soluble part is. The accurate Dr *Alston* has shown, that the crusts weigh double of the lime dissolved; and that they get this additional weight from earth, or perhaps somewhat else, attracted from the water. Twelve grains of crusts contain six grains of lime; and therefore the antacid power of the soluble part in these crusts continues the same, though it is now changed from a saline to a terrestrial substance. The crusts calcined in the fire are burnt to quick-lime, and afford a lime-water. Six grains of this quick-lime required 26 drops of the same acid to saturate it. The crusts are found to contain only the ninth part of water; allowing then for the ninth part of water dispelled, the fire by calcination increased the alkaline quality of the whole
crusts

crusts about a ninth part. But if we consider what a small proportion of these calcined crusts are soluble in water, we must allow, that the soluble saline part of these crusts have their alkaline quality increased in a much greater proportion. These experiments shew evidently the nature of this soluble salt of lime. I would gladly chuse to have more data before I proceed to determine how it becomes unsoluble again; yet there is no harm in attempting a little theory on the data we have, especially as we will be supported by the preceding experiments.

THE whole contents got by *Exp.* 125. & 126. from 8 gr. of salt and 6 gills of lime-water, were 15 or 16 gr. In the quantity of lime-water used in these experiments, there are betwixt 4 and 5 gr. of soluble lime; which, with the 8 of alkaline salt, and 3 more coming partly from the water and partly from the air, just make out the 15 gr. Whence then comes the precipitated powder? Is it from the lime, or from the alkaline salts? There is a quality in this precipitated powder, which will

help us in this question. I found in the course of these experiments, that the powder precipitated, in boiling, from the pearl salts, or, in other words, their earthy base, was not a calcarious earth, or could not be turned to quick-lime. The powder precipitated in the foregoing experiments afforded me, at three different trials, lime-water. Hence a plain, and, I think, an undoubted conclusion arises, that the precipitation comes from the saline part of the lime, and consists mostly of it.

It appears by one of these experiments, N^o 126. that the powder precipitated is more than the quantity of soluble lime in the lime-water. This appears yet stronger from the following

Exp. 128. Six drachms of quick-lime were mixed with eight *English* pints of water. The lime was well dried in a hot fire. When the lime-water was sufficiently strong, it was strained off. From this lime-water I precipitated, by the means of alkaline salts, 42 gr. of a powder; while the lime, dried

as

Se&t. II. ON BLEACHING. 277

as it had been before, and weighed, had lost only 24 gr.

To four pints of lime-water made with lime of another kind, I added 20 gr. of salt of wormwood. The powder precipitated, weighed 19 gr. when gently dried; when kept nearer the fire, it weighed 8 gr. After it had been kept two hours in a strong fire, it weighed but 4 gr. and was then quick-lime. The liquor, when evaporated, gave 19 gr. of an indissolvable powder; five or six of which must have arisen from the earth of the water. These experiments shew us, that the alkaline salts lose something, and that the lime gains something; and that the soluble lime has become insoluble by this addition. If this additional substance is again dispelled by the fire, the insoluble lime becomes soluble again. But what this additional substance is, whether air, an acid, or whatever other principle it is which makes part of the alkaline salts, I leave to the determination of experiment. It is probably air, as no air arises when alkaline salts are added to lime-water, although
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there is a great intestine motion. It does not appear to be an alkaline body; for alkaline salts turn more so by losing it, as appears by

Exp. 129. Four grains of this caustic salt destroyed 16 gutts of spirit of nitre; but 4 gr. of plain alkaline salts destroyed only 12 gutts. Hence it appears, that the substance attracted from the alkaline salts by the lime is not alkaline. We have already found likewise, that the lime by its addition becomes less alkaline, in proportion to its bulk, than what it was before.

As there are middle natures which seem to join the opposite parts of the creation, the terrestrial and aquatic, the beasts and birds, the fishes and birds, the vegetable and the animal, the mineral and the earthy; lime seems to me to be a substance designed by the author of all to connect the salts and earths, two substances that differ widely from one another. It sometimes exists in the one shape, and sometimes in the other. By fire it becomes soluble in water, but not

Sect. II. ON BLEACHING. 279

in a great degree : by the contact and influence of the air, it becomes an unsoluble earth ; still however not so much so, but that it may again be reduced, by a certain degree of heat, to its soluble saline state. Thus much I thought was due to a substance of such general use in the bleachfield, and whose nature and composition was so little understood.

HAVING oncē established the cause of hard waters, we are at liberty to use the analytic method, and account, from that cause, for their different effects. With regard to bleaching, they are of the worst consequence. Soap curdled by hard water, has not its natural effects, as the oil and the salts are separated from one another. The same effects will happen in the bleachfield, when the linen is washed with soap. In this case, the latent oils and dirt will not be loosened by the soapy menstruum. This is the reason that hard water will not wash the dirt out of foul linen. But when the hard water was softened by the alkaline salts, it washed as well as the softest water.

AGAIN,

AGAIN, whenever hard water is mixed with the lye, it must turn immediately thick. This disadvantage can be cured, by allowing the lye to stand for some time, and drawing off the clear liquor. But there is another which cannot: the acid in the hard water joins the alkaline salts in the lye, reduces them to a neutral state, and consequently renders them of no effect in bleaching.

BUT these are not the only disadvantages of hard water in the bleachfield. These salts, thrown on the linen along with the water, must penetrate where-ever the water goes. The sun will soon volatilize the acid part; but the earthy will be left in the substance of the linen, and render it hard and husky. Nothing but an acid can take that earth out, by reducing it again to a saline state. Hence, if more earthy particles are deposited by the watering, than what are carried off by the fousing, the cloth must not only turn hard, but must be tore into holes, and rendered useless. In this way I imagine it hardens pot-herbs which are boiled in it.

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SECT. II. ON BLEACHING. 281

The more of these saline particles are in the water, the more crusts will be formed in the vessels in which it is boiled. Hence we find, that all hard waters deposit much tartarine substance, while no soft water is found to have any such effect. The *Comb* water, as mentioned by Dr *Hales*, is observed to be softer, and to wash linen with a less quantity of soap, than the *Thames* water; while it left no incrustations in the coffee-house boiler, that had been in constant use for fourteen years.

BLEACHERS know very well how to avoid hard waters of the third class; but having no criterion for those of the second, they must often use hard water without knowing it to be so. I have discovered a great degree of hardness in some of their waters. A method, then, of detecting the smallest degree, must be of considerable use to them. Alkaline salts enjoy this property, and have already been of service in this way. Mr *Samuel Hart* had pitched on a spot of ground to make a bleachfield; had examined the spring by the known methods; and thought

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it good. But on trying it by this test, which I had informed him of, he discovered a considerable degree of hardness in it, and fixed his bleachfield on another spot.

As I thought an examination of different springs, in this way, would be of use in showing what is the proportion of hard springs to soft, I desired that gentleman to examine a variety of them, and give me an account of his trials. As he has done it with great pains and accuracy, I shall give the account in his own words.

“ I here send you an account of the several trials I have made of waters, by a solution of salts. These trials were generally performed between *September 10.* and *October 15.* and when the weather was dry and fair.

“ I shall begin with those made on some springs in the neighbourhood of my bleachfield at *Ford*, viz. on the lands of *Vogrie*, *Chesterhall*, and *Crichton*. The first spring tried was on *Vogrie*, commonly

SECT. II. ON BLEACHING. 283

“ monly called *Haly well*; which, on mix-
“ ing the salts, became immediately turbid,
“ and of a bluish colour; and, after fifteen
“ minutes standing, suspended many white,
“ fleecy particles, which in about three
“ hours were altogether precipitated, and
“ the water remained pure as at first.
“ These particles were more copious and
“ ponderous than what I have observed
“ from any other water. This I learned
“ from the great quantity deposited, and
“ the quick precipitation. I observed all a-
“ round this spring great quantities of lime-
“ stone, through which I conceived it pass-
“ ed, and to which I ascribe its hardness.
“ I have been further confirmed in this, by
“ every trial made of water from lime-
“ stone; having constantly the same ap-
“ pearance with this now mentioned, in a
“ greater or lesser degree. The following
“ experiment will afford a further proof.
“ Observing near this a great confluence of
“ springs, which proceeded also from lime-
“ stone, and emptied themselves into the
“ *Tyne*, near the same spot, and knowing
“ the general opinion, that river-water is

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“ soft,

“ soft, I determined to try, how far these
“ springs affected it with their quality, and
“ found the river-water here partook of it
“ in a considerable degree. At first, on the
“ mixture of the salts, it remained pure,
“ and continued so for about fifteen minutes,
“ at which time it suspended a blue
“ cloudy substance in the middle of the
“ glass. I had not leisure to attend its further
“ progress; but no doubt it would have
“ deposited a white powder like the other,
“ though not so copious.

“ As I had a design of fixing my bleach-
“ field here, induced by the largeness of
“ the spring, I was led to a further trial,
“ by filtering the spring through the soil,
“ which is a light brown earth, with a
“ small mixture of sand, in hopes of soft-
“ ening it thereby. For which purpose I
“ caused two pits to be dug, about three
“ and a half feet deep, turning the spring
“ into the upper one; which, when filled,
“ after some hours filtered through the
“ soil to the lower pit: from which, two
“ days after, when the water had settled,
“ and

SECT. II. ON BLEACHING. 285

“ and become pure, I made trial with the
“ salts; and was surpris'd to see it more
“ turbid than when taken immediately from
“ the spring. I made repeated trials, and
“ found it invariably the same. I imagine
“ it had acquired an accretion of salts by
“ passing through the soil; but this I leave
“ to you to determine. I made trial of
“ five other springs on *Vogrie*; two of which
“ proved like this, but not altogether so
“ hard. The other three, which rose on the
“ high grounds, were quite soft, remaining
“ pure with the salts after many hours
“ standing. The chief and last spring
“ which I tried on *Vogrie*, and which also
“ rises on the high ground through a bed
“ of white sand, is a strong run of water,
“ known by the name of the *Carse well*.
“ This is the spring I have chosen to sup-
“ ply my bleachfield. After mixing the
“ salts with some of this water, it continued
“ quite pure for three days, the time I
“ kept it in the glass: and as from this
“ favourable appearance I had reason to
“ think the spring very soft, I determin'd,
“ from other corroborating proofs, to be
“ farther

“ farther assured; for which purpose I
 “ made two comparative trials with water
 “ from another spring, which I had found
 “ very soft, but not altogether so much as
 “ this, and might be reckoned next in qua-
 “ lity. This water had remained pure for
 “ above two hours, and then discovered a
 “ very small, and rare light cloud, scarce
 “ perceptible by the eye, and that only in
 “ a certain light. I took two wine-glasses
 “ of each water; in one of each I put some
 “ hard white soap, pared down, to be dis-
 “ solved; in the other two, some galls. I
 “ perceived, that the soap in the *Carse* well
 “ water more readily and equally incorpo-
 “ rated, and the gall produced more spee-
 “ dily a stronger tincture than in the other
 “ water. This proof determined me.

“ THREE springs I tried on *Crickton*
 “ ground were of the same nature with
 “ *Haly* well, but were longer in discolour-
 “ ing, and deposited a much smaller quan-
 “ tity of white powder.

“ OF four springs I tried on *Chesterhall*,
 “ I

Sect. II. ON BLEACHING. 287

“ I found three quite soft: the other had
“ some small degree of hardness; it conti-
“ nued pure for about an hour and an half;
“ when it suspended, about half an inch
“ from the surface, a light and rare blue
“ cloud. In brief, I made trial of about
“ twenty other springs, and found always
“ the smallest degree of hardness discover-
“ able by the salts. The several waters I
“ tried, may be ranged into three classes,
“ viz. such as continued pure; such as
“ suspended only a light cloud, after stand-
“ ing some hours, and deposited very little
“ powder; and, lastly, such as became
“ immediately turbid, and diffused their
“ foulness through all the water; which
“ commonly appeared of a milky colour.
“ I always observed those springs that pro-
“ ceeded from sand and gravel to be soft, as
“ those from lime-stone to be hard. I shall
“ only communicate one further trial, with
“ which I shall conclude, and which I on-
“ ly acquaint you with, as being similar to
“ the trial made at *Vogrie*, of filtering wa-
“ ter. On seeing a pool of standing water
“ which had filtered from the *Tyne* near
“ *Nisbet*,

“ *Nisbet*, through much the same stratum
 “ as at *Vogrie*, I made trial with the salts;
 “ and found, although I had taken it up
 “ quite pure, that it became immediately
 “ very turbid, to much the same degree
 “ with that at *Vogrie*. From whence it
 “ may be observed, that though hard water,
 “ when percolated through sand or gravel,
 “ may be considerably corrected and soft-
 “ ened; yet that every soil, through which
 “ water can penetrate, will not produce this
 “ effect, is evident from the two former
 “ recited experiments. It will then follow,
 “ that sand or gravel is the only soil we
 “ know of that is proper to soften water by
 “ filtering. I take this occasion to return
 “ you my hearty thanks for the favour you
 “ have done me, in communicating the
 “ method of proving water by salts; and
 “ am,” &c.

Salton, Dec. 26. 1753.

Exp. 130. To try what effect hard wa-
 ters, softened in the preceding way, would
 have on vegetables, I boiled some pease in
 soft water, some in hard water, some in
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Sect. II. ON BLEACHING. 289

the hard water softened with alkaline salts, and some in lime-water. Whenever the pease became soft in the soft water, the whole was removed from the fire. The pease in the hard waters, and in the lime-water, were too hard to be eat; but those in the hard water softened, were so soft, that very few of the pease remained entire. Thus tea, malt, &c. must yield a much stronger tincture to softened, than they do to hard water. I poured equal quantities of hard water, and hard water softened, on equal quantities of Bohea tea. The tea was stronger with the latter water than with the former.

THE antiseptic quality of hard waters discovered by *Exp.* 86. is not taken notice of, so far as I remember, by any author except *Celsus*. He has these words: *Aqua dura, i. e. ea quæ tarde putrescit*. According to him, this antiseptic quality is the characteristical mark of hard waters. Let us try some experiments with regard to this quality of hard waters.

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Exp.

Exp. 131. Nov. 12. An ounce and an half of beef was put into a glass with 6 oz. of soft water. The same quantity of beef was put into another glass with the same quantity of hard water. The same was done in two other glasses, with the same quantity of fish. *Nov. 22.* The fish and flesh in the soft waters were putrified, but the others were quite sound. *Nov. 27.* A piece of each of the latter being roasted on a fork, were firm and good, but somewhat dry. *Dec. 2.* Both spoiled. Hence we discover, that hard waters have a strong power of preserving bodies, and may be made use of in this way with success. Waters three times harder than this, as I have discovered those of *Newcastle* to be, must have a very strong antiseptic power.

To discover the comparative antiseptic qualities of several substances, I made the following trial.

Exp. 132. Dec. 1. One ounce of beef was put into a glass containing eight ounces of soft water. I shall call this glass N^o 1.

N^o 2.

Sect. II. ON BLEACHING. 291

N^o 2. contained the same, with the addition of a scruple of common sea salt. N^o 3. contained the same, with the addition of 2 dr. of the same sea salt. N^o 4. contained the same, with the addition of a scruple of the crystals of pure sea salt. N^o 5. with the addition of 2 dr. of the same salt. N^o 6. contained the same quantity of beef, with the same quantity of hard water. N^o 7. the same quantity of beef, and fresh-made lime-water. N^o 8. the same quantity of beef, and tar-water. *Dec.* 8. N^o 4. & 5. began to smell putrid, the latter not so strong as the former. N^o 2. just begins to have a little smell, but not near so much as any of the two former. *Dec.* 16. N^o 1. & 3. begin to smell. N^o 2. very putrid. N^o 7. is likewise very putrid; and still so hard, that it curdled soap. N^o 6. quite fresh, with a quantity of air-bubbles on the surface of the water; which shows a beginning change. *Dec.* 26. N^o 6. smells putrid. N^o 8. continues still sound.

FROM this experiment the following conclusions arise. 1st, This hard water appears

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pears to be a stronger antiseptic than lime-water *, but not so strong as tar-water. 2dly, Two drachms of pure sea salt, dissolved in 8 oz. of soft water, increased considerably

* There is a difference in opinion with regard to the antiseptic effects of this soluble part of lime, betwixt two gentlemen, to whom the world is much indebted for many ingenious and accurate experiments; I mean Dr *Alston* and Dr *Pringle*. The former says, that the soluble part of lime, or lime-water, is antiseptic; the latter, that it is not. When such ingenious gentlemen, who reason and form conclusions from experiment alone, differ in opinion, it must be from their viewing things in different circumstances and situations. I am always apt to conclude in such cases, that both opinions are, in some measure, true. It is then worth our labour to discover by experiment, what difference in the circumstances of these gentlemen's experiments gave rise to such a difference in their conclusions. I am the more particularly called upon to give my opinion in this question, as two letters of mine, which were not designed to be made public, have been, by a mistake, published in the *Philosophical Transactions*.

Exp. 1. Dec. 6. I put two haddocks in an earthen pot, which held $3\frac{1}{2}$ *English* pints, and filled it with lime-water. One lb. of beef was put in another pot of the same bigness, and filled with lime-water. After they had stood, well corked, eighteen days, the former was quite sweet, and smelt like good lime-water; but the latter had a putrid smell, though not very strong. One of the fish was partly boiled, and partly dressed on the gridiron; and it eat both ways very well, though a little soft, and retaining somewhat

siderably its septic power. 3dly, Two drachms of common salt preserved the flesh twice as long as the same quantity of pure salt. This must have been owing to the mixture

somewhat of the taste of lime-water. The flesh was a little tainted, and of a whitish colour, when prepared in the same way. Fresh lime-water was put on both, the former being poured off. When they had stood four weeks longer, the fish was quite fresh, and appeared somewhat swelled; but the flesh was very putrid. When the fish was put into boiling water, it dissolved immediately into a gelly. Lime-water appears, then, to destroy the cohering principle in fish.

Exp. 2. March 26. I hung about 3 oz. of flesh and a small haddock in the open air in the kitchen; put the same quantities of these two substances in two different pots filled with common water, ordering the water to be changed every day; and the same quantities of the same substances into two pots, such as I mentioned in the former experiment.

April 2. The fish and flesh in the air were dried; the fish had no bad smell, but the flesh was tainted: the fish and flesh in common water smelt strong: the fish in the lime-water was sweet, but the flesh smelt as strong as that in the common water.

Exp. 3. May 18. Into four different glasses, each of which held 3 gills of lime-water, I put four different substances; into the first 1 oz. of beef; into the second the same of lamb; into the third the same of mutton; into the fourth the same of whiting; and corked them. 26. The glass containing the lamb stank much; the beef and mutton were a little corrupted; but the fish quite sound. *June 2.*

The

ture of the bittern with the former; and shews, that these two salts have very different effects.

The fish was still sweet, but all the flesh smelt very strong: the lime-water in which the beef was, appeared of a high red colour; that in which the mutton was, appeared less red; that with the lamb was but gently tingured; that with the fish was still white. The lamb seemed most putrid. *June 7.* Fish sound. 26. Fish was putrid. *Aug. 6.* The fish smelt more offensively than any of the former.

Would not any one be apt to conclude from these three experiments, that lime-water preserved fish, and not flesh? I did so; but was soon convinced of my error by the following experiment.

Exp. 4. May 19. Into an earthen pot, holding $3\frac{1}{2}$ English pints of common water, I put $1\frac{1}{2}$ oz. of mutton; into another, holding the same quantity of lime-water, I put the same quantity of mutton. 26. The mutton in common water was putrid, but that in the lime-water was not. *June 7.* Flesh in the lime-water still sweet. 26. Still sound. *Aug. 6.* Was a little putrid.

It appears, then, from these experiments, that lime-water is antiseptic, with regard to flesh, when used in a certain quantity, and when the pieces of flesh are so small that the lime-water can easily penetrate them; that lime-water is antiseptic, with regard to fish, in a greater degree, probably because it more easily penetrates fish, from its less firm texture; and that the difference of these two ingenious gentlemen's conclusions arose, probably, from their using, in their experiments, different quantities of flesh and lime-water.

WE could easily account for all the bad effects of hard water on the human body; and show, that, by the separation of the acid from the terrestrial base, which must happen in the body, several diseases must arise; such as, the stone and gravel, rheumatism, colics, gout, and many others; but this is not the proper place. These unhealthful effects of hard water may be easily prevented, by mixing alkaline salts with it. The hard water I have used in these experiments, takes about 1 dr. to one *English* pint: A very small quantity to produce so excellent an effect. The milky water must be allowed to stand till it becomes clear, before it is used for drink.

To discover whether the effect of hardening vegetables depended on the acid, or on the earthy particles left in the substance, I tried the following experiment.

Exp. 133. Four different parcels of green pease were boiled, for the same time, in the same degree of heat, in four different waters; *viz.* soft water; hard water; artificial

ficial hard water, made with the absorbent base of the hard water, and the oil of vitriol; and some soft water, with as many drops of the spirit of nitre in it as I thought was equal to the acid of the hard water. When the pease of the soft water were enough boiled for eating, I took out the whole. The pease in the hard water were so hard, that they could not be eaten; and at the same time not so green as those in the soft water. Those in the artificial hard water were like the former. Those in the water with the nitrous acid did not taste acid, were lighter-coloured, and softer than the rest; their skins were mostly broke. The earth was found before not to harden water, and the acid is now. Hence it must arise from the saline particles entering compounded, and the acid leaving the earthy behind; which, from the volatility of the former, must soon happen. Hard water, though it does not make vegetables greener, as is generally thought; yet as it keeps them longer hard, it keeps them longer green.

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SECT. II. ON BLEACHING. 297

THIS method which we have discovered * of softening hard waters, is easy, expeditious, and cheap; qualities absolutely necessary to render it useful to the public. It is easy, as the most ignorant can do it; expeditious, as it becomes fit for all family-uses immediately, and for drinking in half an hour; and cheap, as the material costs but a mere trifle; nay may be prepared by any person. By this change, the hard water not only becomes fit for all the common uses of life, but as beneficial as it was before hurtful to the health of man. Lord *Verulam* had so high an opinion of the salutary effects of nitre, that, as we are told, he used to mix it with all the water he drank. Hard water, when corrected by al-

* I have discovered, since these papers were in the press, that Dr *Shaw*, in his chymical discourses, has given an imperfect hint of this quality of alkaline salts. He says, that hard water becomes softer by an addition of alkaline salts. I call this hint imperfect, because hard waters may be made softer, and yet continue hard, as they admit of various degrees of hardness. The foregoing experiments show, that all kinds of hard waters are altogether softened by alkaline salts. Nor does the Doctor inform us of the manner of doing it, or reasons on which it depends, or qualities of the water after it is softened.

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kaline salts, turns into soft water impregnated with nitre. I may venture to affirm, that no other material can ever be found capable of softening hard water: and tho' one was discovered endued with the same property, it could not be of the same use to mankind, as there is none, alkaline salts excepted, to be had every where. A particular substance or plant was only to be found in particular places, but this material is to be got where-ever plants grow. So kind is the general parent of nature, that he has provided a remedy, every where to be found, for so common an evil; but, at the same time, has left the discovery to our own industry.

How much we stood in need of such a discovery, most great towns, especially those on the sea-coast, nay the greatest part of some counties, can testify. *Newcastle* is a remarkable instance of this distress. In all the pants or pipes there, two excepted, the water is hard; and to such a degree, that it is three times more so than the hard water which I have examined. The nitrous
acid,

Sect. II. ON BLEACHING. 299

acid, joined to an absorbent base, is the cause. The precipitation from these waters, by the means of alkaline salts, was in so great plenty, that the fourth part of the glass was covered with it, and amazed not a little those who made use of the water. There the old and infirm complain, that these hard waters give them a sourness of the stomach, and colics.

As the strength of different alkaline salts differ, and as some hard waters are much harder than others, nay the same water harder in dry than in wet weather, some easy and certain general rule of softening all hard waters is necessary; the following appears to me the best. Let a certain quantity of alkaline salt be dissolved in a certain quantity of soft water. Into a certain quantity of hard water in a glass pour in the solution gradually, so long as the milky colour is on the increase. When that is at the height, let the water stand till it becomes pellucid. Try it again with a few drops of the solution; if no whiteness arises in the water, it is then soft; if there does,

go on drop by drop until no more white clouds arise. By this means it is known what quantity of salts is necessary to soften that quantity of water; and, consequently, how much any given quantity of water will require.

Quær. 1. Is not hard water more nourishing for vegetables than soft water? I imagine, that the salt of vegetables enters their vessels in such a form as this salt of hard waters. The salt likewise seems to be of the nitrous kind; which we think the nourishment of plants. As this query is opposite to the general opinion, (for no gardener will make use of hard water, if he can shun it), I watered some plants with it, and thought that they grew better than those which were watered with soft water.

Quær. 2. May not hard water be proper for some particular constitutions, and for some particular diseases, such as putrid fevers, &c.? The antiseptic quality of these waters would seem to be useful to putrescent habits.

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Quær. 3. Do these hard waters supply the air with a nitrous acid? We have discovered by these experiments, that the nitrous acid of this water is easily separated, by a boiling heat, from its absorbent base; and that it arises even by a gentle distillation. We find likewise, that all hard waters deposit more or less of an absorbent earth. Hence we may reasonably conclude, that there is a real nitrous acid, distinct from the vitriolic acid, communicated by these hard waters, to the air; and that from the former, and not from the latter, as chymists have imagined, nitre is generated. This is further confirmed by an observation of the learned Dr *Plummer*, who says, that he has oftener observed nitre produced or regenerated, than vitriolated tartar, from an alkaline lixive long exposed to the air.

Quær. 4. Is not hard water more proper to be carried to sea than soft water, as it appears to resist putrefaction very powerfully?

Quær. 5. Is not the cause of hard and petrifying

petrifying waters the same? and do not they differ only in degree? When the saline substance impregnates the water very strongly, the earth, deposited in the interstices of any substance, must be continually on the increase, till at last the substance becomes a stone. This I imagine is the way that all petrifying waters act, and accounts very naturally for their effects.

Quer. 6. Do not the brewers, in great cities, who generally make use of hard water, lose a very great part of the substance of their malt, as we have found hard water very unfit for drawing a tincture from any vegetable? Will not hard water, softened in this way, make ale of a much greater strength from the same quantity of malt? and what effect will nitre have on ale?

Quer. 7. Do hard waters contribute to sterility, as *Hippocrates* asserts?

Quer. 8. Must not hard waters have in general a very bad effect on digestion, as they
tend

Sect. II. ON BLEACHING. 303

tend to keep all bodies in their natural found state ?

Quær. 9. How happens it that *Bristol* water is reckoned so exceedingly soft, in-
somuch that it is thought to come from
chalk, when it is really a hard water?
What acid does it contain ? Are not its ef-
fects in consumptive hectic cases owing to
this imperfect neutral salt ?

Quær. 10. Is not the effect of hard water
in turning pewter black, owing to a so-
lution of the metal by the acid ?

Quær. 11. Are all waters hard which lie
at a considerable depth below the surface of
the earth ? and is it not necessary that these
should have some particles in their compo-
sition of an antiseptic nature, to resist the ef-
fects of heat and stagnation, to which they
are liable ?

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S E C T. III.

*The effects of steel and coal waters on cloth,
and the cure.*

HARDNESS is not the only pernicious quality in waters which the bleacher has to shun. All impregnations with bodies suspended in that fluid, whether they are earthy, saline, or metallic, retard, nay often entirely stop the whitening of cloth. There are two species of waters particularly destructive in this art, I mean vitriolic or chalybeate waters, and coal waters. As these are very common in this country, the bleacher ought to be more upon his guard against them. It therefore becomes necessary for him to be able to distinguish them from other waters, and to remove their bad effects when they happen to be used.

ALL steel waters, whether the iron be dissolved by an acid or not, depositate a red substance, called *ochre*. This is to be observed in the channel where these waters

run.

Sect. III. ON BLEACHING. 305

run. It is mostly composed of the particles of iron precipitated to the bottom, with a small addition of whatever saline substance exists in the water. These particles are deposited, continually, on the surface of the cloth, when watered with a chalybeate water, and effectually stop all further progress in whiteness. This happened to a poor woman, who watered some webs she was bleaching from a spring near her own house. To her great surprise they turned redder and redder every day. Not being able to account for this effect in a natural way, or to remove that colour, she imputed it to witchcraft, blamed the neighbour she hated most, and sold them for a trifle. That water was afterwards discovered to be a mineral spring.

HAD she consulted a chymist, he would have shown her a method of dissolving the charm. Water, with the addition of a small proportion of oil of vitriol, would have carried off the ochrey matter. I watered some white linen with the *Hartfield* spaw water, till it had acquired a pretty strong red

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colour. This linen steeped in water gently acidulated with vitriol, in a few hours, came out white again. I am not sure, however, whether all ochres can be dissolved by acids. I have tried some which were not. Against these I know no remedy.

It is therefore of great consequence to the bleacher, that he should be able to distinguish these waters, when he meets them, from others, in order to shun them in the situation of his bleachfield. The characteristic mark of these waters, is, That they turn purple or black with galls, green tea, or the leaves or bark of the oak. If this effect happens, on the mixture of these bodies, the water is improper for bleaching.

THERE is an ochrey substance, like the former in appearance, which has not yet, so far as I know, undergone any examination; I mean that of coal waters. Whenever they are used in the watering of cloth, they leave a yellow colour. That we may be able to remove these particles when lying on the surface of cloth, it becomes necessary to examine

Sect. III. ON BLEACHING. 307

amine their nature, and to discover their proper solvent.

THIS examination will be attended with another advantage. This ochrey substance is reckoned one of the surest marks of coal. But how can it be depended on, when many waters, which do not come from coal, have a like appearance, and when the distinguishing properties of these similar substances are not ascertained? A chymical examination is the only method to fix these. I have elsewhere examined the ochre of mineral waters, and discovered its properties and nature *. I shall endeavour, here, to do the same with that of coal waters. The ochre I made use of was taken up carefully from the channel of a coal-level, and had been kept by me near a year.

Exp. 134. The ochre of coal waters has no particular taste, and feels in the mouth gritty, and not fat, as that of mineral waters does.

* Essay on *Dunse* spaw.

WHEN put on a red-hot iron, it sparkles, but emits no sulphureous or acid steams.

HALF a drachm of it mixed with warm water, and the liquor strained and evaporated, gave a small quantity of a saline residuum, which liquified in the air, tasted sharp, and rendered half an ounce of water reddish and hard. Paper dipped in this liquor, burnt like a match, and discovered the salt to be nitrous.

IT effervesced with water acidulated with oil of vitriol. The liquor, with an addition of galls, turned into an ink. When thrown on melted nitre, it sparkled, but did not de-flagrate.

THE magnet has no effect on it before calcination. Twenty grains, calcined for two hours in a fire, were reduced to 14, and were all attracted by the magnet.

Two drachms and a half were distilled, and gave me about $1\frac{1}{2}$ dr. of a liquor, which turned syrup of violets green, effervesced
with

Sect. IV. ON BLEACHING. 309

with mineral and vegetable acids, and had the smell of spirit of hartshorn.

FROM this experiment, then, we discover the nature and properties of coal ochre. We see that it is compounded of iron, and a neutral salt, like that of all hard waters. We observe, likewise, its proper solvent, oil of vitriol diluted with water; and that the same mixture which removes the ochre of mineral waters, will remove this. But what is perhaps of greater moment, its properties appear to be very different from those of other ochres. If such a substance was presented to me, I think I could tell whether it came from coal or not.

S E C T. IV.

Some considerations with regard to the further improvement of our linen manufacture.

THE demand for manufactures is in proportion to their goodness and cheapness. That country which affords the

the best, and at the lowest prices, will find the readiest market. To these two points must every designed improvement tend. For that end the foregoing experiments were calculated. I have endeavoured, by their assistance, to show where the common practice was right, and where wrong; to propose some improvements in it; to introduce new materials made at home; and to shorten the time of some operations considerably; to explain the principles upon which the whole is conducted; and, in short, to make the bleachers understand their art thoroughly; the only method to make them operate better and cheaper, without diminishing their gains.

I am very sensible how difficult a thing it is to alter the established opinions of mankind; and how much more difficult to alter their practice. As the experiments in this disquisition have been many, and the reasonings few, the author can never expect to pass for a theorist: but considering the prejudices of mankind, the trouble of making proper trials, and the qualities requi-

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Sect. IV. ON BLEACHING. 311

sute for such a work, their effects in the bleachfield must be but very slow. It is reasonable they should be so. Alterations in the common practice of the arts are too dangerous, both for the public and particulars, to be hastily gone into. But yet when Experience points the way, it is unpardonable to neglect its advice.

HAVING now secured the most important and dangerous part of our linen manufacture, let us cast our eyes on the other branches, and consider if there be not room likewise for further improvement in these. Every manufacturing country ought, if possible, to have the materials of their manufacture produced within the country; that it may not depend upon foreigners, nay perhaps upon their rivals in trade, whether they shall have a manufacture or not. The Honourable board of trustees for fisheries and manufactures have given all attention to this point; and, by proper regulations and premiums, have endeavoured to encourage the growth of flax at home: but all they have done has been yet attended with little success;

cess; and I am afraid, if some speedy assistance is not given, things will rather turn worse than better. Complaints have been made by manufacturers, that our home flax is not so good as the foreign. I am of opinion, that it is more owing to our want of skill in watering of it, than to our soil, or methods of managing it there. We have all kinds of grounds, and excellent rules laid down for their culture: but the process of watering seems not yet thoroughly understood; and the practice, as carried on by the commonalty all over the country, is most destructive to the flax. As it is of such importance to our manufacture, and as it is a chymical operation, we think it deserves our consideration, in a treatise designed to improve our manufacture by the assistance of chymistry.

WHOEVER will attend to what passes during the steeping of lint in standing water, and during fair weather, or will make the experiment in the house, must find it attended with the following circumstances. On the second or third day, if the weather
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Sect. IV. ON BLEACHING. 313

is warm, a great many air-bubbles arise to the surface of the water, and by degrees a scum or pellicle gathers there, which is full of these air-bubbles. The water gains a small degree of heat, and a corrupted smell. If the flax is allowed to lie too long, it turns corrupted, black, and loses all tenacity. These effects evidently show, that the process of steeping flax is the process of putrefaction carried on to a certain length.

EVERY one knows, that the intention of steeping is to loosen the harl or bark of the flax from the bun or woody part of that plant; and that it is to be accomplished by a solution of the oil, or mucilaginous substance, which makes them cohere. Putrefaction is the instrument at present employed to attain that end. The intestine motion raised by it, disunites, attenuates, and dissolves that vegetable glue, and renders it miscible with water. The great art is to know when that is done. If the flax is allowed to lie any longer in the water, that oil which unites the solid particles of the

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harl is dissolved, and the fibres lose all strength.

THE time which flax must lie in the water, is to be measured, then, entirely by the quickness or slowness of the putrefaction. As this depends on the concurrence of many circumstances, *viz.* the nature of the flax, its quantity, the heat of the weather, length of the nights, nature and quantity of the water, and many others, it is impossible to fix a certain time. The flax, when sufficiently watered, acquires a slippery oiliness on its skin, owing to a solution of that mucilage mentioned before: but *Pliny's* rule is still the most certain, *Maceratos indicio est membrana laxatior, lib. 19.* The flax ought therefore to be inspected, after the fourth day, every six hours; and when the bun appears brittle, and the harl separates from it, the flax ought to be immediately taken out. Nor ought we to wait, as is judiciously observed in the *Dublin* essays, till the separation becomes too easy; but leave that to be completed by the dews and warmth when exposed on the grass. As the danger

Sect. IV. ON BLEACHING. 315

is great in allowing it to lie too long, so there are several bad effects arising from taking it out too soon. The black bars which run across the linen, and are so difficult to remove in bleaching, are none of the least. To whiten these, the rest of the cloth is often damaged. When flax has been kept somewhat too long in the water, none of these black bars are to be seen. They increase in proportion to the deficiency or failure in that degree of putrefaction necessary to steeping. I am told by an experienced bleacher, that he prevents, in a great measure, these black bars, by souring the yarn after it has been boiled with ashes.

WHEN we once understand how this process is carried on by nature, we will soon see what is the business of art. We must regulate the process of putrefaction so that it does not meet with too great obstacles to stop it, nor be allowed to go on too rapidly. The latter must seldom be the case in this climate; but the former often. Running water must appear at first sight entirely improper for steeping lint, as the corrupted

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particles are continually carried off. Springs have the same fault in a lesser degree. Nothing promotes putrefaction so much as quietness and heat; nothing stops it more than agitation and cold. Steeping ought always then to be performed in a place as much sheltered from the winds, and in a season when it will have as much heat as possible. I would chuse that the water should not be too shallow, that it may not be too suddenly affected by the coldness of the night, or other changes of weather. The more uniform the heat of the water is, the more safe the process will be. Ponds made at the sides of lakes or of rivers, not too near their source, appear in general to be the most eligible places. If the process goes on too slow, on account of the nature of the lint, water, or weather, chymistry teaches us how to quicken it. The putrid fermentation can be checked or quickened, as well as the vinous. As yeast increases the latter, so do all putrid bodies the former. Some putrid vegetable substance mixed with the water, would answer this purpose.

FROM

SECT. IV. ON BLEACHING. 317

FROM what has been said, we may easily account for the practice of the *Dutch*, who lay the dirt and mire found at the bottom of their steeping ponds, on the surface of the flax after it is laid in the water. When that corruptible matter lies there, it communicates putrefaction to the water more equally than if it lay at the bottom. We likewise see the reason why those who understand the steeping of flax, never allow it to touch the ground: for when that happens, the flax which lies there, bearing the pressure of all above it, putrifies sooner and faster than what lies above. We may likewise account for another fact, that flax must lie four or five months in moss-water before it is sufficiently watered. Moss-water, so far from corrupting, preserves even animal bodies from corruption. This water is too much used in this country, and highly prejudicial to the flax.

BUT, of all waters, none seem so bad as those which have a considerable degree of hardness, because these have already shown themselves to be almost incorruptible.

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Common practice had discovered this without knowing the reason of it, and therefore hard waters are marked as improper. If they must be used, we are ordered to fill the ponds, and expose the water to the sun for some weeks *. But it has appeared from undoubted experiments, that there are many degrees of hardness, which have not hitherto been discoverable; and that exposition to the sun is not a remedy against hard waters. We have discovered a criterion for the former, by which we are able to perceive the smallest degrees of hardness; and a cure for the latter, in case we are necessitated to use it. Let us then, by experiment, try the effects of hard water on flax; and see if these effects can be removed, by being softened in the way I have described.

Exp. 135. Sept. 11. I steeped equal quantities of flax in three different kinds of waters, *viz.* hard water, the same softened with alkaline salts, and soft water. The last, though it broke soap, and was the soft-

* Vid. *Dublin Essays.*

Sect. IV. ON BLEACHING. 319

est in the place where I tried this experiment, was not so soft as I could have wished. On the 14th they all had a scum, with air-bubbles on their surface; but the hard water had the least. On the 17th all the waters had a putrid smell; the hard and soft waters were pale-coloured, but the hard water softened was of a high colour. On adding some alkaline salts to a cupful of the soft water, it turned almost as high in the colour as the former. The flax in the softened water, was the only one of the three whose skin felt oily. Some of each parcel being dried, that taken out of the softened water was of a higher colour than the other two, and was rather too much watered; that from the soft water not sufficiently; that from the hard water no better than when put in. On the 20th, the flax in the soft water appeared to be completely watered. On the 24th, the flax in the hard water was almost watered, but its skin did not feel slippery as the others had done. This experiment shows the bad effects of hard water in steeping flax, and at the same time how to cure these.

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THE process of putrefaction, by which the present method of steeping flax is carried on, admits of too great variety with regard to weather and water, and is too dangerous to be managed with safety by the commonalty. It would be much for our advantage, and I have often thought it possible, to discover a safer method than that at present used. I was inclined to think, that the addition of alkaline salts to the water might answer that purpose. For the qualities requisite in such a body, were to resist putrefaction, and dissolve the oil betwixt the harl and the bun; and these two qualities appeared to me to be inherent in these salts. As I never make any use of theory, but to lead me to experiment, I made the following.

Exp. 136. Sept. 26. Some flax was steeped in soft water; an equal parcel in the same quantity of water, with the addition of 2 dr. of pearl salts to each *English* pint and a half; another parcel in the same quantity of water, with 1 oz. instead of 2 dr. *Oct. 2.* The first parcel was sufficiently steeped; the
second

Sect. IV. ON BLEACHING. 321

second not fit for taking out ; and the third still further removed from that state. *Oct. 7.* The second was finished ; but when dried, seemed very brittle. The third was no better than when put in.

THE next thing to the relation of successful experiments, is the relation of unsuccessful ones. Even these are attended with many advantages. However unsuccessful the last has been, I do not yet despair of finding out some body which will answer all the ends of putrefaction without the danger of it. In the mean time, it appears highly necessary, that steeping should be made a business distinct from the raising of flax. In *Holland* it is managed by lint-dressers, who buy the flax standing on the ground.

I am apt to think, that the great stop to the progress of our linen manufacture lies in this very point, the steeping of flax. Our farmers, by the wise regulations of the board of Trustees, seem to understand the culture of flax well enough ; and, notwithstanding

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some small disadvantages from the nature of our climate, would raise it in sufficient quantity, and find their profit in it, if they could dispose of it, before steeping, to a set of people who understood that process. The farmer is at present unwilling to deal in it, because, though he raises flax of the best kind, it is generally spoiled in the watering, and becomes of less value than the foreign. The steeping and dressing of flax ought, therefore, to be made a distinct business; and, as it is the branch of our linen manufacture least understood, should be most encouraged. All premiums in arts and manufactures, ought to be directed to those branches which are least understood. It would seem at first necessary to bring over a set of *Dutch* lint-dressers, by proper encouragement, and that premiums should be given to those lint-dressers who produced the greatest quantities of the best dressed *Scots* lint.

FROM what I have said on bleaching, it appears, that cloth, from its hard and firm texture, resists for a long time the entrance
of

Sect. IV. ON BLEACHING. 323

of those materials which are to whiten it. But the lint and yarn are not subject to this objection. Would it not, then, save a great deal of trouble, expence, and hazard, if these were bleached, at least in part, before they went into the loom? I am afraid it would not be so easy to manage the lint, as it is so light a body: but as for the yarn, I can discover no material objection against it. One I have heard, and that is, The yarn would become too oozy. But that fault, I imagine, could be corrected by the weaving, and the gentle bleaching which would afterwards be necessary.

IT is the opinion of all the bleachers, that the cloth of this country is of too thick a fabric, owing to the coarseness of the woof. I agree with them. That species of cloth requires so many buckings before the salts can penetrate into the inner parts, that the external threads are too often destroyed before the internal are whitened. On the contrary, the thinness of the opposite species of cloths is more than counterbalanced by the preservation of its fabric in the bleach-

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field. Besides, the expence of bleaching thin cloth is not near so great as that of bleaching thick. The former retain their colour better, and appear finer at the same price; which will always recommend them to the merchant.

THERE is nothing promotes an art faster than the communication of those who practise it; nothing retards it more than a selfish spirit of keeping all a secret. It is by a gradual progress, where one refines upon the inventions of another, and not by the endeavours of a single person, that arts arrive at perfection. I cannot, then, but recommend to the Honourable Board of Trustees, a scheme of Mr *John Chrystie*. He not only has made many advances himself in this art, but is desirous that others should do the same. He proposes, that every bleacher, especially those who have got, or expect any premium from the Trustees, should annually deliver an exact account of his method of bleaching. If this proposal took place, several faults would be observed and corrected; several advantages gained; the

Sect. IV. ON BLEACHING. 325

the bleachers made more knowing, as one may excel in a particular branch, who is very deficient in all the rest; a complete history of the practice made out; and the art itself arrive at perfection. Let those who shelter themselves under the appearance of secrets, know, that ignorance always does the same.

I know nothing that must have been of greater advantage to the linen manufacture of *Ireland*, than their linen hall. The manufacturer brings his cloth there, is provided by the public with a proper apartment for his goods, and is sure of a market in a few days. The public, having the cloth under its eye, is assured of its goodness, and proves a continual check to private frauds. The foreign merchant, knowing where he can supply himself at once, is under no necessity of acting by commission at a distance, or if he should come, of dealing with retailers; but resorts to this market, and makes his bargain with the manufacturer himself. These considerations make their cloth go better and cheaper to foreign markets, and are alone sufficient to overpower
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any nation who does not follow such a prudent conduct.

To you, Gentlemen, who are possessed of landed estates, I must now apply myself. You are, or may be, the great promoters and directors of industry among your tenants and dependents. It is from you that the commonalty will take that bias of mind, which makes them useful or useless servants of the public. It is in your power, by procuring materials at the cheapest rates ; by encouraging the industrious, and discouraging the slothful ; by small premiums to excite emulation ; by taking the rents of your houses in manufactured goods, rather than money ; by instituting markets at proper times for the sale of yarn ; and by many other methods, to raise a spirit of labour and industry.

THERE is nothing seems more to be desired, than a change in the education of the young people of both sexes. While it continues on the present plan, of educating them, at a public school, to reading, writing, and computing, I have no hopes of seeing them
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Sect. IV. ON BLEACHING. 327

very industrious. That habit can only be got when young. By the present plan they are a burden on their parents till they are fully grown up, while they might be acquiring strong habits of industry, earning their own bread, and adding to the wealth of their country. The consequences of this education are visible, after the men have applied to day-labour ; for they know not how to turn to any account four or five hours every night during the winter, too much time to be lost, and which might yield a considerable advantage, if they had been taught spinning, or any other species of manufacture. It is well if this turn to speculative knowledge, which they have got, is attended with no worse consequences. It would be for the advantage of this country, nay for the real happiness of its inhabitants, that we had spinning-mistresses, as well as schoolmasters, in every parish.

NECESSITY is allowed to be the greatest spur to industry. People work not for pleasure, but for a livelihood. When that is easily procured, as in cheap years, industry
abates ;

abates ; when with greater difficulty, as in dear years, industry increases. I have often thought, that those sorry cloaths, houses, and meals, to which our commonalty has been accustomed, instead of being assistants, as they may appear at first sight, were great enemies to our growing manufactures. Our people work but in proportion to their demands ; and if at any time they have more money than supplies them, it is spent in drink. It is only the gentlemen who can bring about a change in these articles. Till I can see a greater degree of refinement ; till I can hear that our commonalty are possessed of stronger desires with regard to those conveniencies of life than they are at present, I shall expect no change in their activity.

It is to the government we must chiefly be indebted for the progress of our linen manufacture. It is there alone that ease can be had from the duties on soap and ashes, which bear hard on our manufacture. It is there alone that a constant market can be provided for us, by encouraging the exportation

Sect. IV. ON BLEACHING. 329

portation of our own, and discouraging that of foreign cloth; and by other methods which the wisdom of the nation shall think proper. Without some proper and speedy encouragement of this kind, our manufacture must soon decline; perhaps it does so at present. No industry on our side can possibly counterbalance those heavy taxes which we pay on all the necessaries of life, and which our rivals in trade know nothing of. If we are obliged to give up the linen, we must endeavour to cultivate the woollen manufacture, whose seeds are already sown in this country.

I look on it as a loss to *Great Britain*, and to arts and manufactures, that we have no academy instituted by public authority, and at the public charge, to which the care and further progress of these might be intrusted; and whose members, secured in a decent livelihood, might follow the natural bent of their genius; and hear, with safety, the enthusiastic voice of Fame. What a trifling sum to *France* is the yearly expence of the Academy of Sciences! and yet of

330 EXPERIMENTS. Part IV.

what benefit has it been to the arts and manufactures of that country! Their superiority in many arts, and especially in dying, has been entirely owing to the labours of this society. *Lewis XIV.* in whose reign this academy was instituted, has gained victories by it over those whom his sword could not subdue.

F I N I S.



